Aquaponic Monitoring System and Fish Feeding with Favoriot

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Muhammad Azeem Syazwan Mohd Noordin[1], Sharifah Saon[1](✉),
Abd Kadir Mahamad[1], Mazlan Abbas[2]
[1] Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
[2] Favoriot Sdn Bhd, Selangor, Malaysia
sharifa@uthm.edu.my

Abstract—The advantages of hydroponics and aquaculture are combined in the agricultural technique known as aquaponics. An Internet of Things (IoT) aquaponics system is used to help collect vast amounts of ecological and agricultural data. An aquaponics system, including a fish tank and planting area, has been completed and set up as an experimental field. The major goals of this project are to create an IoT aquaponics monitoring system that may be used for a variety of purposes. This project utilises Arduino, WiFi shield and Android applications for monitoring purposes. A pH sensor, temperature and servo motor are used to retrieve and store the data on the Favoriot IoT platform. The sensors' results were degree temperature, soil moisture, pH, and automatic fish feeder. The system acquires an average performance of 92.5%, considering the data receive and system functionality. In conclusion, the project can monitor the water temperature, moisture, pH and provide notifications through the mobile application of the aquaponic monitoring system.

Keywords—Aquaponic, Internet of Things, Favoriot, mobile application

1 Introduction

Figure 1 shows an aquaponic system, which is a method of growing plants in water and using this as a habitat for rearing fish. Users can use the best hydroponics and aquaculture by growing plants and rearing fish. In hydroponics, users essentially grow plants in water that is often pumped out of the system in aquaculture, where nutritional toxicity from the fish is accumulated [1]. The water must be continuously syphoned off and replenished with a clean supply due to fish feeding and waste [2, 3]. Not only is water saved through continuous cycling, but toxic nutrients also make the recycled water safe for the fish again. An IoT aquaponic system is proposed to make things easier and more efficient to operate, especially for farmers. With the application of advanced techniques and technologies, farm yields can be increased, improve product quality, reduce water and nutirent usage, and reduce the environmental impact of food production.

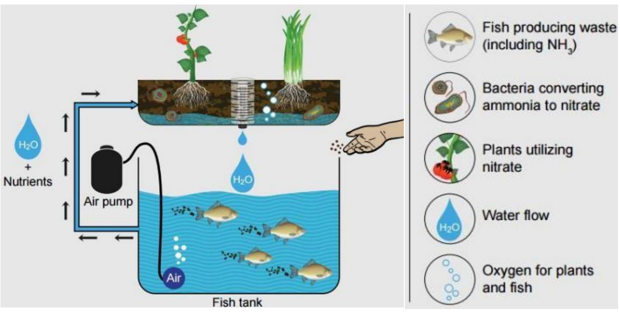


Fig. 1. Aquaponic system [3]

IoT technological advancements can help with the collection of vast amounts of ecological and agronomic data [4, 5]. A smart aquaponic system that uses the Internet of Things (IoT) to monitor and maintain the appropriate properties such as temperature, water PH, soil humidity, and many more. It notifies a user to keep aquaponic in good condition for plants and fish. It eases and reduces the need for human involvement [5-9]. That is mainly concerned with water waste, which is a significant global issue [10]. This approach is made to fit any environment and the country's economy. It's a novel approach that combines hydroponics and aquaculture in a scenario. Aquaponics farming would be a solution with the evolution of IoT and mobile applications, as previous agricultural procedures were tiresome and time-consuming.

The main objectives of this project are to develop and design an IoT monitoring system for Aquaponic to improve the efficiency, productivity and sustainability of the aquaponic system. Firstly, to design a real-time IoT monitoring system for aquaponic uses of sensors with the Favoriot IoT platform to collect and transmit data. Next, to develop an Android application for real-time monitoring purposes based on the Favoriot IoT platform. Lastly, to analyse the performance of the developed system, including pH, moisture and temperature obtained from the systems, an SMS notification system is activated once any issues are detected before they become problems. The project focused on working with the Favoriot IoT platform for data collection, transmission and analysis. This project uses several sensors; DS18B20 temperature and moisture sensor module, with the addition of an automatic fish feeding system. This project also works with Android Studio applications to develop mobile application monitoring systems.

2 Literature review

In an isolated system, fish and vegetables are grown using the new sustainable food production method known as aquaponics. An aquaponic system's effectiveness, output, and sustainability depend on several variables, including the water's quality, temperature, pH, and nutrient levels. Monitoring and optimising these parameters in real-time is critical to ensure the health and growth of the fish and plants and minimise the system's environmental impact. Recent advancements in the IoT technology have enabled the development of low-cost, wireless sensors that can monitor these parameters and transmit the data to a centralised server for analysis. An IoT-based aquaponic monitoring system can provide real-time data on the health and growth of fish and plants, allowing farmers to make informed decisions on feed, water, and nutrient management. It can also help prevent disease outbreaks, optimise resource use, and reduce aquaponics' environmental impact.

2.1 Aquaponic monitoring system using Arduino

A well-liked design concept for an affordable and scalable method to monitor various environmental factors in aquaponic systems is an IoT monitoring system that utilising Arduino. Arduino, an open-source electronic board, reacts as a brain to control all the programmed activities. Low power consumption, self-sufficiency, and cost-effectiveness are why Arduino is notorious to developers worldwide. The Arduino community is dedicated to designing and manufacturing single-board microcontrollers for digital devices. According to [11], two sections of Arduino were used as a central processing unit. The Arduino Mega, Grove-Mega shield, and relay board are all in one section used to communicate with the sensors and actuators from the data acquisition and rectification unit. Besides, Grove-Mega Shield is used as an alternative to traditional breadboards. The connections were reduced by mounting them on top of the Arduino Mega. The relay board enables Arduino to control the actuators turning on and off. Researchers in [12] suggested a system consisting of an Arduino nano-based open-source development board hardware WRTnode, a webcam for data collection, and smart sensors for investigating and processing man-machine interfaces. This smart monitoring and control system focused on the flow of meters, pH, ultrasonic distance, and temperature sensors. In [13], a smart aquaponic system is developed using Arduino Uno as a central unit to control input and output sensors. The authors agree that Arduino Uno consists of 14 digital signals, sufficient to execute the project since the aquaponic system is not that large compared to the project that uses Arduino Mega as its central unit. Arduino Nano, 7 Uno and Mega have advantages and disadvantages, depending on how the user wants to acquire the data. This project uses an input voltage of approximately 7-12 volts, that the reason the Arduino Uno is considered for the aquaponics monitoring system.

2.2 Internet of Things (IoT)

Internet of Things (IoT) ecosystems are complex and require specialised knowledge to provide a decent and meaningful solution. The middleware, which connects the hardware and the application, is one of the essential components. It should have various tools that enable developers to manage and deploy devices and data efficiently [2, 4, 7-9]. However, developing it from scratch can be a lengthy and time-consuming process. The Favoriot IoT platform is designed to facilitate the integration of data from numerous sensors, actuators, and other data sources. Data collection and storage from IoT devices have gotten considerably simpler.

Additionally, the platform allows developers to design vertical apps. Developers are not required to host or store the data generated by their IoT devices. Favoriot's Rest API allows devices to submit data to the Favoriot middleware platform. An external application may retrieve data from the Favoriot middleware platform using the Rest API.

In 2018, the Malaysian Communications and Multimedia Commission (MCMC) with the Internet of Things (IoT) Technical Regulatory Aspects & Key challenges listed the Favoriot as one of the IoT platforms that provide cloud services to store analogue data, especially temperature and humidity [14].

Favoriot is an enterprise IoT platform offering enhanced security, more customisation, better support and control. Favoriot is used in the smart aquaponic system to ensure the developed project's success.

2.3 Water quality in Aquaponic

By 2050, it is reported that there will be areas with little or no freshwater [15]. Thus aquaponic is considered one of the solutions to growing a fish; however, water quality is a critical issue in aquaponic systems and is essential to maintaining water quality because it affects both plants and fish [16]. The correct parameters, including temperatures (22 – 32 °C), pH (6 – 7), ammonia (< 3 mg/L), nitrite (0 – 1 mg/L), and dissolved oxygen (> 5 mg/L), are required to ensure both plants and fish are in good condition [7, 17]. This range of parameter values must be required to build a stable aquaponic system [17]. However, the water temperature averages 26 °C daily, resulting in fish and plants living longer and growing very healthy [18].

2.4 Feeding rate

Fish feeds are designed to give fish the nourishment they need to grow and stay healthy [19]. A feeding rate design calculation by [20] shows how to balance an aquaponic system between fish and plants. The size of tanks, fish stock rate, plant, and production must be controlled in a way that the system receives an average daily feeding ratio. The optimal feeding rate ratio is determined by various parameters, including the types of aquaponics used, the types of plants, and the chemical composition. The feeding rate ratio is set between 60 to 100 grams of fish food per day per square meter of plant growth [21, 22].

3 Methodology

3.1 Design concept

The IoT aquaponics monitoring system is designed to monitor the condition of the water, temperature, and moisture. The system collects data from sensors and stores it in the Favoriot database. It can be monitored and controlled using a web server and mobile applications that are provided by the cost-effective Favoriot IoT platform [23].

The block diagram in Figure 2 consists of Arduino Uno together with a WiFi shield as a central processing unit that receives input signals from DS18B20, pH and moisture sensors and sends the data to a Favoriot IoT platform. This IoT aquaponics monitoring system design concept can provide real-time data, scalability, flexibility, and cost-effectiveness.

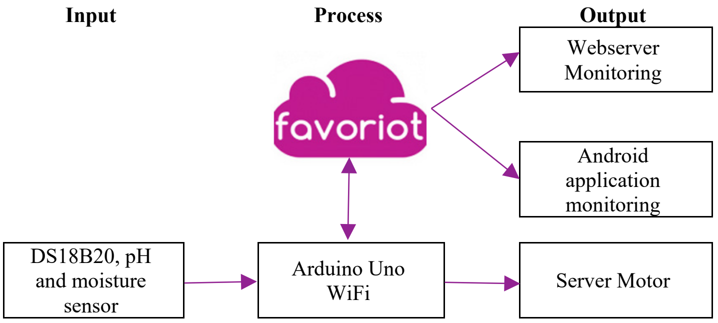


Fig. 2. Project block diagram

3.2 Project diagram

The circuit consists of DS18B20, moisture and pH sensor. From Figure 3, a sensor is required to connect with analogue sensors. Specifically for pH sensor, an extra calculation is needed as the sensor output still needs calibration to work successfully.

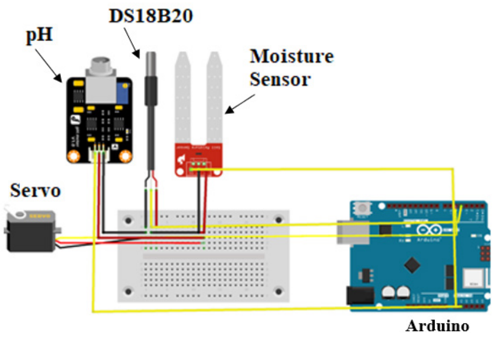
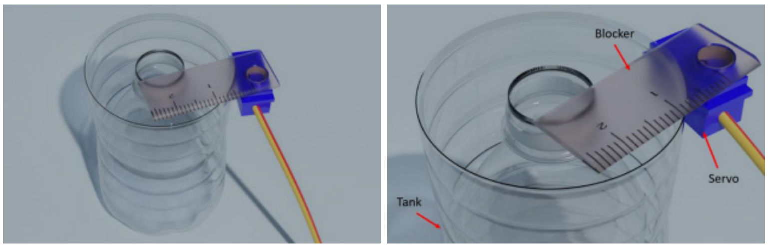


Fig. 3. Project circuit

3.3 Fish feeder

This proof-of-concept (PoC) fish feeder is a custom-made product consisting of a plastic base feeder tank with a servo motor and blocker. Using a plastic base tank is made for the reason of cost-effectiveness. The tank size is around ~700 to 900 millilitres and can store 100 gram fish pellets [22]. Figure 4 is a 3D model of a custom-made fish feeder.

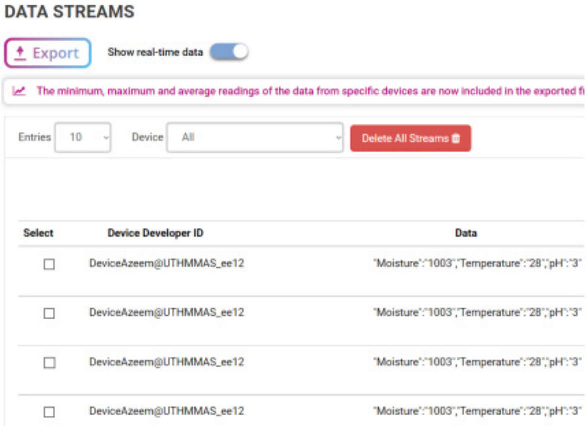


(a) (b)

Fig. 4. 3D fish feeder model of (a) top and (b) close-up

3.4 Favoriot data stream

Favoriot is used mainly for collecting data and controlling several rules that have been set through the platform. Figure 5 shows the data streams of the Favoriot platform retrieved every 30 seconds.



DATA STREAMS

The minimum, maximum and average readings of the data from specific devices are now included in the exported fi

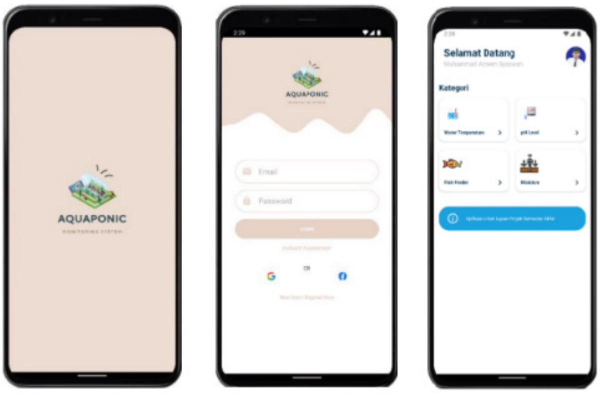
Entries 10 Device All

Select	Device Developer ID	Data
☐	DeviceAzeem@UTHMMAS_ee12	"Moisture":"1003","Temperature":"28","pH":"3"
☐	DeviceAzeem@UTHMMAS_ee12	"Moisture":"1003","Temperature":"28","pH":"3"
☐	DeviceAzeem@UTHMMAS_ee12	"Moisture":"1003","Temperature":"28","pH":"3"
☐	DeviceAzeem@UTHMMAS_ee12	"Moisture":"1003","Temperature":"28","pH":"3"

Fig. 5. Favoriot data stream

3.5 Android studio

The IoT aquaponic monitoring system application was developed to make it easier for the user to monitor the system every time and everywhere. Water level monitoring, pH, soil moisture, and fish feed are the features of the application. The application logo on the front page, login page, and main menu is shown in the application as in Figure 6.



(a) (b) (c)

Fig. 6. Android mobile application of smart aquaponic monitoring system; (a) front page, (b) login page, and (c) main menu interface

4 Result and discussion

The system installed at the aquaponic tank to collect all parameters is shown in Figure 7, which details the component and sensors of the developed monitoring system, can be referred to as in Figure 3.

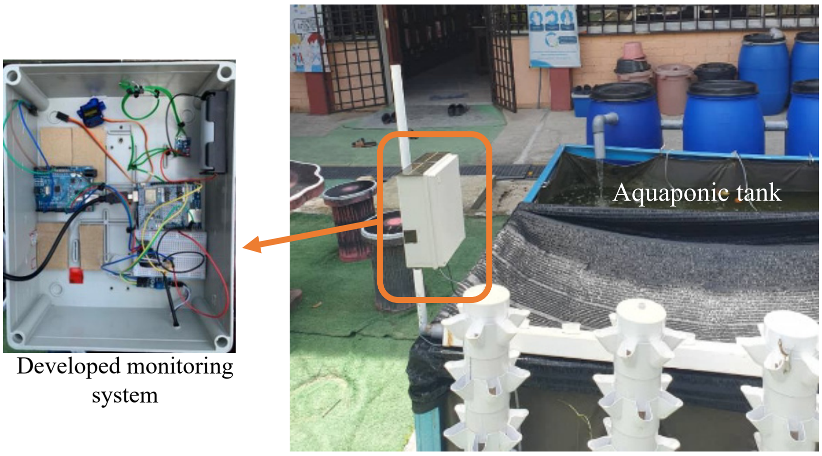


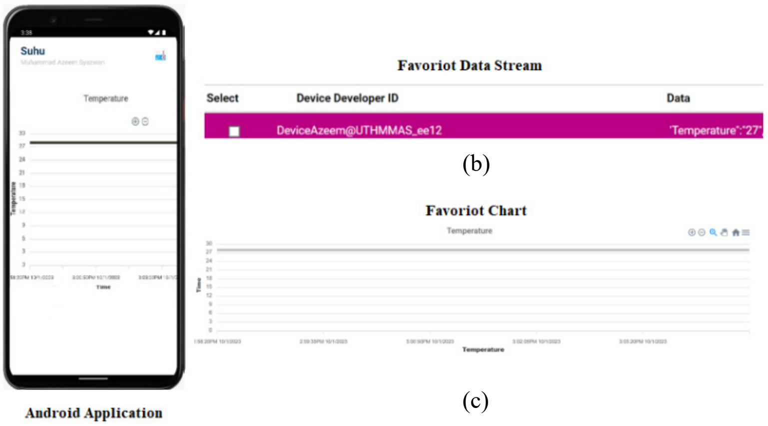
Fig. 7. Installation of developed monitoring system

4.1 Water temperature

The study was to observe the water temperature to see if it exceeded the normal temperature needed for the aquaponic system. Table 1 shows ten sample temperatures for ten days during the evening. Figure 8 shows that the data transmitted to Favoriot has been successfully retrieved and can be viewed on the Android application.

Table 1. Temperature data for day ten during the evening

No	Device Id	Temperature (°C)	Date	Time PM
1	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:04:34
2	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:04:03
3	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:03:32
4	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:03:01
5	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:02:30
6	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:01:59
7	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:01:27
8	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:00:56
9	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	3:00:25
10	DeviceAzeem@UTHMMAS_ee12	27	10/1/2023	2:59:53



Select	Device Developer ID	Data
☐	DeviceAzeem@UTHMMAS_ee12	'Temperature':'27'

Android Application

(a)

(b)

(c)

Fig. 8. Data stream of 27°C viewed on (a) mobile application, (b) Favoriot data stream, and (c) Favoriot chart

As referred to Figure 9, it can assume that the temperature value is in an excellent range for an aquaponic system. No Favoriot Rule triggered because of temperature not exceeding 33°C. Higher temperatures occur on the 3rd day and lower temperatures on the 2nd day because of particular reason, the issue discussed in Section 4.2.

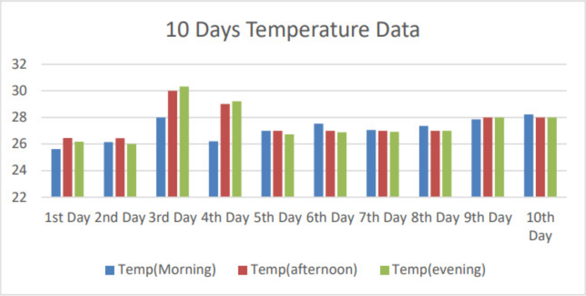


Fig. 9. Bar Chart of temperatures data for ten days

4.2 Effect of weather on water temperature

Temperature data are collected using a DS18B20 sensor during morning, afternoon and evening for ten days by considering different weather conditions as shown in Table 2, by referring to accuweather.com.

Table 2. Weather Conditions for ten days

Day	Morning	Afternoon	Evening
1	Rainy	Rainy	Rainy
2	Rainy	Rainy	Rainy
3	Not Rainy	Not Rainy	Not Rainy
4	Rainy	Not Rainy	Not Rainy
5	Not Rainy	Not Rainy	Not Rainy
6	Not Rainy	Rainy	Not Rainy
7	Not Rainy	Not Rainy	Not Rainy
8	Not Rainy	Not Rainy	Not Rainy
9	Not Rainy	Not Rainy	Not Rainy
10	Not Rainy	Not Rainy	Not Rainy

From Figure 9, the temperature level for the 1st and 2nd day is lower compared to the 3rd to day 10th. It may occur because of the weather conditions. The weather conditions on the 1st and 2nd days are rainy, while the 3rd to the 10th are sunny. It is because rainwater temperatures are different than the tank; contrasting the temperature between them alters the tank's normal temperature levels. However, that rain would cause the water temperature to decrease because of reduced photosynthesis, as cloudy skies inhibit effective oxygen production [24]. In conclusion, the water temperature value is affected by weather conditions.

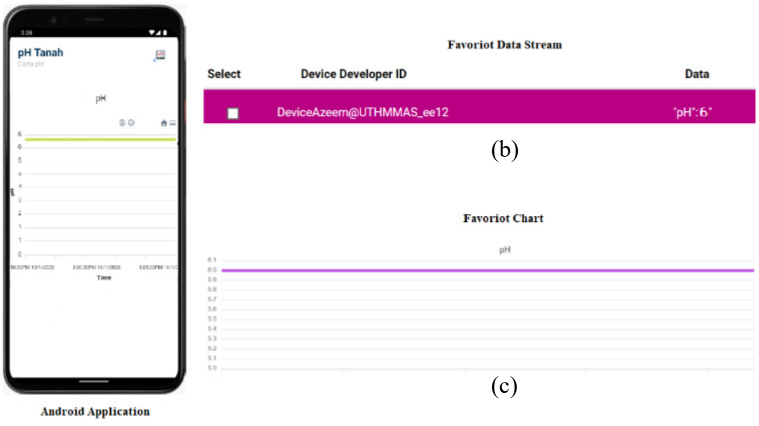
4.3 pH value

pH value was taken for ten days for observation of aquaponic pH water. The good aquaponic system requires a range of pH around 6–7 [7, 17, 25]. However, there is instability due to an environmental factor that caused the pH reading to jitter around 6-7. Table 3 shows ten pH samples for day ten during the evening. Figure 10 shows that data transmitted to Favoriot has been successfully retrieved and can be viewed on the Android application.

pH results are more accurate if the calibration process is correct. Based on Figure 11, pH water on 2nd, 3rd, and 9th day have the same pH value for each period (morning, afternoon and evening) compared to the other days.

Table 3. pH Samples for day ten

No	Device id	pH	Date	Time PM
1	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:04:34
2	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:04:03
3	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:03:32
4	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:03:01
5	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:02:30
6	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:01:59
7	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:01:27
8	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:00:56
9	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	3:00:25
10	DeviceAzeem@UTHMMAS_ee12	6	10/1/2023	2:59:53



☐ DeviceAzeem@UTHMMAS_ee12 "pH":6"

(a)

(b)

(c)

Fig. 10. pH data stream on (a) mobile application, (b) Favoriot Data stream, and (c) Favaroit chart

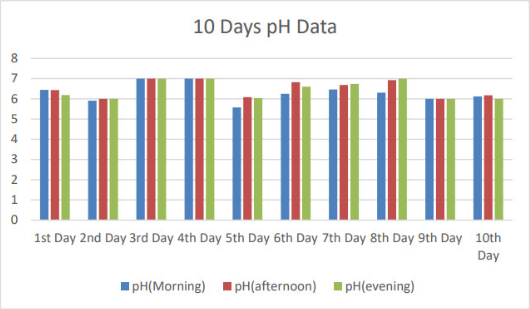


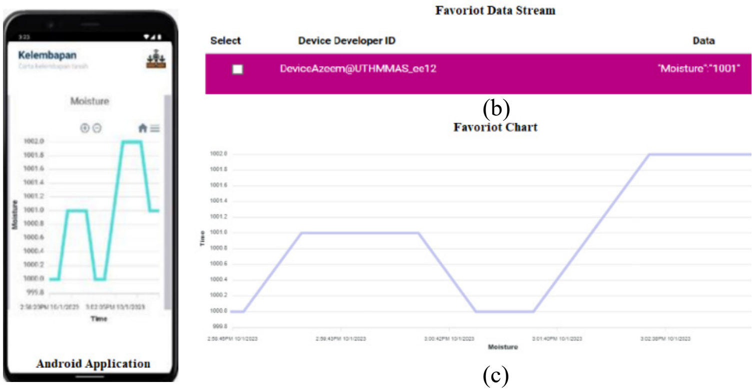
Fig. 11. Bar Chart shows pH data for ten days

4.4 Moisture value

An aquaponic system requires a moisture range of 750-1200. Table 4 shows a ten moisture sample for day ten, during the evening. Figure 12 shows that data transmitted to Favoriot is successfully retrieved and can be viewed on the Android application.

Table 4. Moisture samples data for day ten

No	Device id	Moisture	Date	Time PM
1	DeviceAzeem@UTHMMAS_ee12	1001	10/1/2023	3:04:34
2	DeviceAzeem@UTHMMAS_ee12	1001	10/1/2023	3:04:03
3	DeviceAzeem@UTHMMAS_ee12	1002	10/1/2023	3:03:32
4	DeviceAzeem@UTHMMAS_ee12	1002	10/1/2023	3:03:01
5	DeviceAzeem@UTHMMAS_ee12	1002	10/1/2023	3:02:30
6	DeviceAzeem@UTHMMAS_ee12	1001	10/1/2023	3:01:59
7	DeviceAzeem@UTHMMAS_ee12	1000	10/1/2023	3:01:27
8	DeviceAzeem@UTHMMAS_ee12	1000	10/1/2023	3:00:56
9	DeviceAzeem@UTHMMAS_ee12	1001	10/1/2023	3:00:25
10	DeviceAzeem@UTHMMAS_ee12	1001	10/1/2023	2:59:53



Select	Device Developer ID	Data
☐	DeviceAzeem@UTHMMAS_ee12	"Moisture":"1001"

(a) (b) (c)

Fig. 12. Moisture data stream on (a) mobile application, (b) Favoriot Data stream, and (c) Favoriot chart

Based on Figure 13, moisture is set to be low in the morning compared to the other period. Weather conditions and humidity are becoming a factor in how it affects soil moisture parameters. The effect of humidity on plants is more significant as it is lower in the morning and higher in the evening [26].

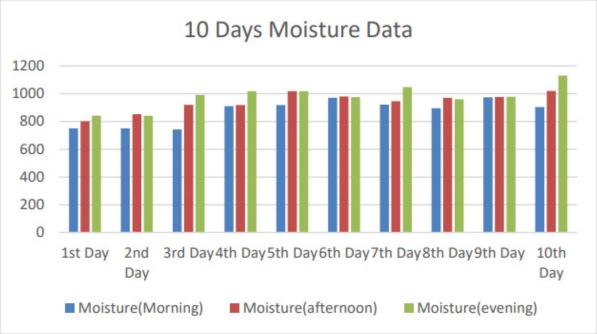


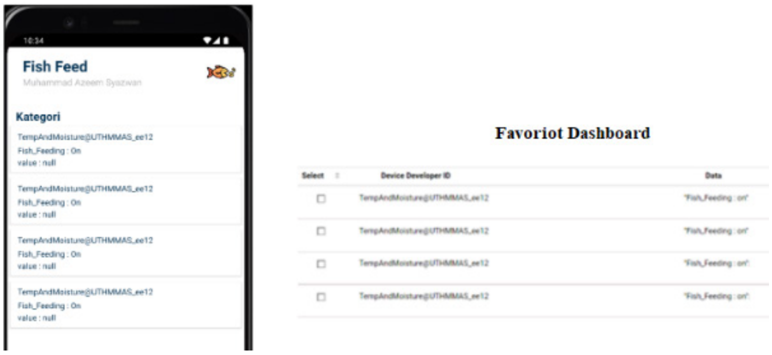
Fig. 13. Bar chart shows moisture data for ten days

4.5 Fish feed

Fish demand sufficient nutrients and the appropriate feeding ratio needs to be maintained [17, 20, 21]. Fish feeding is set twice a day. The fish feeder is always in "off" mode and will be "on" and running automatically at the set time (7 a.m. and 5 p.m.) Table 5 indicates fish feeder activities for five days. Users can also monitor the activity of fish feeding on Android applications and the Favoriot platform, as shown in Figure 14. Servo motors are automatically activated at 7 a.m. and 5 p.m. Only the "on" status appears in the Favoriot data stream and Android application as an indicator to show that the fish feeder is running.

Table 5. Fish feed data for five days

No	Device id	Fish_feeding State	Date	Time
1	TempAndMoisture@UTHMMAS_ee12	On	23/12/2022	7:20:56 AM
2	TempAndMoisture@UTHMMAS_ee12	On	23/12/2022	17:20:25 PM
3	TempAndMoisture@UTHMMAS_ee12	On	25/12/2022	7:20:56 AM
4	TempAndMoisture@UTHMMAS_ee12	On	25/12/2022	17:20:25 PM
5	TempAndMoisture@UTHMMAS_ee12	On	27/12/2022	7:20:56 AM
6	TempAndMoisture@UTHMMAS_ee12	On	27/12/2022	17:20:25 PM
7	TempAndMoisture@UTHMMAS_ee12	On	29/12/2022	7:20:56 AM
8	TempAndMoisture@UTHMMAS_ee12	On	29/12/2022	17:20:25 PM
9	TempAndMoisture@UTHMMAS_ee12	On	03/01/2023	7:20:56 AM
10	TempAndMoisture@UTHMMAS_ee12	On	03/01/2023	17:20:25 PM



Fish Feed

Muhammad Azeem Syazwan

Kategori

TempAndMoisture@UTHMMAS_ee12
Fish_Feeding : On
value : null

TempAndMoisture@UTHMMAS_ee12
Fish_Feeding : On
value : null

TempAndMoisture@UTHMMAS_ee12
Fish_Feeding : On
value : null

TempAndMoisture@UTHMMAS_ee12
Fish_Feeding : On
value : null

Favoriot Dashboard

Select	Device Developer ID	Data
☐	TempAndMoisture@UTHMMAS_ee12	"Fish_Feeding : on"
☐	TempAndMoisture@UTHMMAS_ee12	"Fish_Feeding : on"
☐	TempAndMoisture@UTHMMAS_ee12	"Fish_Feeding : on"
☐	TempAndMoisture@UTHMMAS_ee12	"Fish_Feeding : on"

(a) (b)

Fig. 14. Fish feeder data stream on (a) mobile application and (b) Favoriot dashboard

4.6 Fish feed schedule

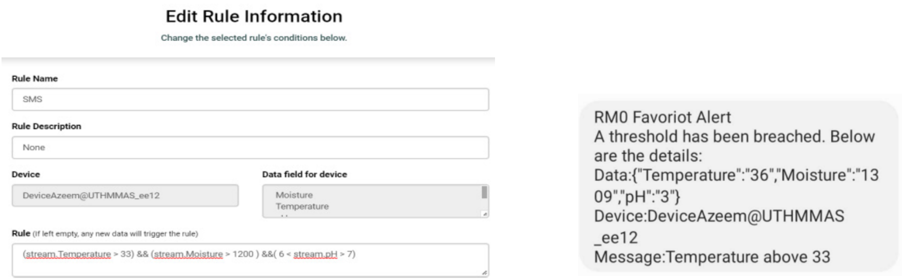
An automatic fish feeder is installed on the system that triggers twice daily. Due to the unavailability of a person in charge that needs to feed manually, an automated system is necessary. The custom-made fish feed, is sufficient to feed Tilapia fish twice daily based on the size of the feeder tank. The system ran successfully daily for ten days, as shown in Table 6. The system's functionality is recorded to monitor the feeding activities and analyse its effectiveness. For comparison and data analysis, the function of the fish feeder was also recorded manually at 7 a.m. and 5 p.m. every day. Bigger tank size is required to make the system run for the longest time.

Table 6. System functionality record

Day	Yes	No	Remarks
1st Day	✓		
2nd Day	✓		
3rd Day		×	Need to refill food
4th Day	✓		
5th Day	✓		
6th Day		×	Need to refill food
7th Day		×	Need to refill food
8th Day	✓		
9th Day	✓		
10th Day	✓		

4.7 Favoriot rules SMS warning

A warning rule of a specific parameter dangerous to the aquaponic system is set up on the Favoriot rule information as shown in Figure 15 (a). The system sends a warning SMS (Figure 15 (b)) to notify users if any parameter of temperature, pH, or moisture sensor breaches a range of values already set up in development.



Edit Rule Information

Change the selected rule's conditions below.

Rule Name: SMS

Rule Description: None

Device: DeviceAzeem@UTHMMAS_ee12

Data field for device: Moisture Temperature

Rule (If left empty, any new data will trigger the rule)

```
(stream.Temperature > 33) && (stream.Moisture > 1200 ) &&( 6 < stream.pH > 7)
```

RM0 Favoriot Alert
A threshold has been breached. Below are the details:
Data:{"Temperature":"36","Moisture":"1309","pH":"3"}
Device:DeviceAzeem@UTHMMAS_ee12
Message:Temperature above 33

(a) (b)

Fig. 15. (a) Favoriot rules and (b) SMS warning notitication

4.8 Summary

Aquaponic monitoring system based on Favoriot was successfully developed and able to operate in different weather conditions. The statistics from this experiment show that the aquaponic parameter sensor output fluctuates as the surrounding environment. This project works with Favoriot and Android applications to monitor data easily. This project helps to maintain an aquaponic system in good condition as it should be. Table 7 shows the difference between the expected value and actual result on average for ten days.

Table 7. Expected Value and Actual Result in Average for ten days

	Water Temperature °C	**Water pH**	**Soil Moisture**	**Fish Feeder (Day of Functionality)**
Expected value	18-33	6-7	750-1200	10 days
Result in average for ten days	27	7	980	7 days

Table 8 shows a performance analysis of water temperature, pH, soil moisture and fish feeder. The overall performance average of the system is 92.5%, considering days of data record and the percentage of data retrieved from the Favoriot platform. Data retrieval for fish feeding is 70% because of a malfunctioning system due to a custom fish feeder's tank needing a refiling before it can be used again.

Table 8. Performance analysis

	Water Temperature °C	**Water pH**	**Soil Moisture**	**Fish Feeder**
Days of data recorded	10	10	10	10
Data successfully retrieved (%)	100%	100%	100%	70%
Overall performance average (%)	92.5%			

5 Conclusion

The development of a monitoring system for aquaponic and an automated feeder are successful and achieved the primary goal of this project, as well as an Android application for real-time monitoring purposes using the Favoriot IoT platform. Developing IoT-based monitoring systems in aquaponics expands the knowledge of real-time monitoring and data management in closed-loop systems. It provides a more detailed and accurate picture of the conditions inside an aquaponic system, allowing for better decision-making on feed, water, and nutrient management. By optimising resource use and reducing the risk of disease outbreaks, farmers can increase their yield and reduce costs, leading to higher profits. Furthermore, efficiently using water, energy, and nutrients can reduce waste and pollution.

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8 Authors

Muhammad Azeem Syazwan received Bachelor Degree in Electronic Engineering from the University Tun Hussein Onn, Malaysia, in 2023. (email: azeemsyazzwan@gmail.com).

Sharifah Saon is currently a Senior Lecturer in the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia. She holds a BSc and Master in Electrical Engineering from Universiti Teknologi Malaysia and Kolej Universiti Tun Hussein Onn Malaysia, respectively. Her research interest is theoretical digital signal processing, visible light communication, digital & data communication, Internet of Things (IoT) application, and big data analysis. She is a member of IEEE, Institute of Engineering Malaysia (IEM), Board of Engineering Malaysia (BEM), and registered Professional Technologist of Malaysia Board of Technologists (MBOT). (email: sharifa@uthm.edu.my).

Abd Kadir Mahamad received his Bachelor of Science in Electrical Engineering (2002) and Master of Electrical Engineering (2005) from University Tun Hussein Onn Malaysia before pursuing a Doctor of Philosophy (Computer Science and Electrical Engineering) at Kumamoto University, Japan (2010). He is currently an Associate Professor at the Faculty of Electrical and Electronic Engineering UTHM and registered as Professional Engineer. From May 2015 through May 2016, he was doing industrial attachment at Melaka ICT Holdings Sdn Bhd as Executive Assistant Manager and was involved in Smart City project in Melaka. He currently leads a video analytics and Internet of Things (IoT) research team. His research interests include Deep Learning, Smart City, Intelligent System applications, and embedded system. He is also a Senior Member of IEEE, Institute of Engineering Malaysia (IEM), and Board of Engineering Malaysia (BEM). (email: kadir@uthm.edu.my).

Mazlan Abbas is the CEO and co-founder of FAVORIOT Sdn Bhd, an IoT company. He is a recognized thought leader in the IoT industry, having been listed as a top 50 influencer by several organizations. He has extensive experience in the telecommunications industry, including as a CEO of REDtone IoT, a senior director at MIMOS Berhad, and various senior management positions at CELCOM. Dr. Mazlan has also worked as a professor at several universities in Malaysia and is currently an Adjunct Professor at the Faculty of Information Science and Technology, MMU. He holds a BEE from Universiti Teknologi Malaysia, a MSc in Telematics from the University of Essex, and a Ph.D. in Telecommunications from Universiti Teknologi Malaysia. He is a frequent speaker at IoT, IR 4.0, Smart Cities, and telco conferences and serves on the Industry Advisory Panel for several universities. He is also a TEDx Speaker and has received an Honorary Doctorate in Electrical Engineering from UTHM. (emial: mazlan@favoriot.com).

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