Journal of Robotics and Control (JRC)
Volume 5, Issue 1, 2024
ISSN: 2715-5072, DOI: 10.18196/jrc.v5i1.18470

IoAT: Internet of Aquaculture Things for Monitoring Water Temperature in Tiger Shrimp Ponds with DS18B20 Sensors and WeMos D1 R2

Ramdan Satra [1], Mokh. Sholihul Hadi [2*], Sujito [3], Febryan [4], Muhammad Hattah Fattah [5], Siti Rahbiah Busaeri [6]
[1, 2, 3] Department of Electrical and Informatics Engineering, Universitas Negeri Malang, Indonesia
[1, 4] Faculty of Computer Science, Universitas Muslim Indonesia, Indonesia
[5] Faculty of Fisheries and Marine Sciences, Universitas Muslim Indonesia, Indonesia
[6] Faculty of Agriculture, Universitas Muslim Indonesia, Indonesia
Email: [1] ramdan.satra.2205349@students.um.ac.id, [2] mokh.sholihul.ft@um.ac.id, [3] sujito.ft@um.ac.id,
[4] febryan1453@gmail.com, [5] muhhattah.fattah@umi.ac.id, [6] sittirahbiah.busaeri@umi.ac.id
*Corresponding Author

Abstract—**Cultivation of tiger prawns stands as a crucial sector in Indonesia's fisheries industry, significantly contributing to the country's foreign exchange. However, challenges persist in the cultivation process, particularly concerning suboptimal harvest outcomes. A critical factor in tiger prawn cultivation is the water temperature within shrimp ponds, a parameter directly influencing shrimp growth. The recommended normal temperature range is 28-31°C. Deviations from this range can adversely impact the shrimp's metabolic system and appetite, resulting in stress and potential mortality. Temperature fluctuations can lead to severe issues such as hindered growth, reduced productivity, and increased shrimp mortality. Real-time monitoring of air temperature emerges as a pivotal element in ensuring the success of shrimp farming. This research aims to provide a practical solution for shrimp cultivation by presenting a system that enables farmers to adjust air temperature in ponds in real-time through a user-friendly website application. The ability to promptly respond to abnormal temperature fluctuations empowers farmers to optimize cultivation conditions, thereby reducing shrimp mortality rates. The research focuses on creating a water temperature monitoring system for tiger prawn ponds using cloud storage through the Firebase platform. By implementing real-time temperature monitoring, financial risks for shrimp farmers can be mitigated, preventing losses attributed to temperature-induced shrimp mortality. The research utilizes the DS18B20 temperature sensor and WeMos D1 R2 as the control center. The website displays air temperature measurements, showcasing a high accuracy of 99% with a minimal error of 1.2%. This underscores the system's effectiveness in measuring air temperature both above and below the pond. The incorporation of IoT technology for monitoring water quality in ponds offers a practical and innovative approach to tiger prawn cultivation, with the potential to enhance production outcomes in each harvest.**

Keywords—Component; Tiger Prawn Aquaculture; Water Temperature Monitoring; Real-time IoT Systems; Cloud Data Storage.

I. INTRODUCTION

Cultivation of tiger shrimp is one of the most crucial aquaculture sectors in Indonesia. This cultivation significantly contributes to the national economy and coastal areas such as Pinrang Regency [1][2]. The economic contribution of shrimp cultivation encompasses the value of shrimp production, shrimp exports, and employment in this sector. Increasing shrimp production can enhance regional and national income. One of the primary challenges in cultivating tiger prawns is maintaining pond environmental conditions, including water temperature, within the optimal range of 28-31°C [3].

Inappropriate water temperatures can have adverse effects on shrimp growth and health. The primary challenge is the unpredictability of temperature fluctuations, especially during seasonal changes or extreme weather events. This can induce stress in shrimp and may lead to mortality if not managed properly. Furthermore, shrimp farming faces challenges contributing to crop failure, such as shrimp diseases, irregular water quality management, unstable variations in pond water temperature, environmental pollution, and other issues. Particularly concerning fluctuations in pond water temperature, real-time water temperature monitoring is crucial to address this concern [4]. One proposed solution to prevent crop failure arising from unstable shrimp pond temperatures is the application of Internet of Things (IoT) technology for continuous monitoring of pond water conditions [5]–[12]. The adoption of IoT-based monitoring facilitates enhanced control for farmers over pond water conditions [13]. In instances of deviations from standard water temperatures, such as an increase above the defined threshold or excessively cold temperatures [14], farmers can implement corrective measures to stabilize water temperatures, such as activating water wheels or replacing water within the pond plot.

The automation of pond water conditions monitoring in shrimp or fish farming has extensively incorporated Internet of Things (IoT) technology [15]–[22]. Previous studies include the development of a water condition monitoring device for fish farming using Arduino [23], [24] through a web interface [25]–[29] Another study focused on monitoring shrimp pond water conditions using an Android mobile application [30]–[34] based on WSN [35]–[41]. Furthermore, research on monitoring temperature and pH levels in vannamei shrimp pond water [7] utilized DS18B20 sensors with an interface for pond water monitoring through a smartphone. Additionally, research on salinity, oxygen levels, and water height monitoring employed ultrasonic technology and the ESP32 microcontroller for data processing, with Wi-Fi technology for data transmission to a cloud server [6],[42]. Supporting studies encompass the application of IoT technology in agricultural waste management [43] and soil humidity monitoring in chili cultivation [44].

Although previous research has contributed to the development of monitoring systems in the fisheries and agriculture sectors [40], [45]–[51], there is still a need for further development, particularly the implementation of IoT in shrimp pond with soil construction. The soil-constructed land poses challenges, especially in hot or rainy weather, which can impact the resilience of the electronic components used, and the pond water conditions can change drastically based on the surrounding environment [52]. It is necessary to conduct testing for the implementation of IoT technology in these soil-constructed areas, especially in measuring pond water temperature. Changes in pond water temperature are highly influenced by the weather conditions at the pond location. Another challenge in shrimp pond with soil construction is the occurrence of corrosion on electronic devices, which can affect the quality of sensors in conducting measurements. These conditions pose a challenge in the implementation of IoT technology in outdoor environments, especially in traditional shrimp pond.

The proposed research utilizes the WeMos D1 R1 microcontroller, an integrated IoT component with Wi-Fi capabilities [53] for communication with a modem as a data transmission medium to a cloud server [51], [54]–[56]. This research also uses the DS18B20 sensor as a component that can provide real-time information on pond water temperature conditions [12]. In this research, cloud technology based on Firebase is combined with a Virtual Private Server (VPS) for data storage [57]. The cloud data storage is not solely focused on Firebase; instead, data obtained from the sensor will be received by Firebase and subsequently stored in the VPS using the MySQL database management system (DBMS) [51]. The aim of this research is to assess the accuracy of the IoT device in measuring pond water temperature and to conduct real-time monitoring processes using smartphones and desktop computers. This study contributes to the control of traditional pond water conditions, enabling farmers to take preventive measures promptly in the event of changes in water temperature that may affect tiger shrimp cultivation.

II. METHOD

A. *Research Stages*

This research uses several important stages which are carried out in stages. The process initiates with 1) Device Preparation, 2) System Analysis, 3) System Design, 4) System Testing, 5) Implementation. Specific details for each stage are elucidated in Fig. 1.

Device Preparation: This stage involves the preparatory measures for devices, commencing with input devices like the DS18B20 water temperature sensor. Subsequently, processing devices, specifically the WeMos D1 R1, along with the MiFI Modem serving as the Gateway, are configured to act as a pivotal intermediary facilitating communication between the microcontroller device and the cloud server.

System Analysis: In this stage, the analysis commences by scrutinizing the data or information acquired during the data collection phase through a comprehensive literature review concerning the implementation of IoT technology for monitoring pond water temperature in shrimp farming.

System Design: The design of the system commences based on the collected data, incorporating the implementation of the DS18B20 sensor-based WeMos D1 R2. Activities in this stage involve creating a block diagram, a system flowchart, and schematic diagrams. Additionally, it includes the development of the equipment box design, which will be implemented in traditional shrimp ponds.

System Testing: The system testing is conducted in the laboratory. Testing is performed using samples of pond water placed in a container, with the IoT device positioned on top of the container. The IoT device is then activated to determine its functionality. Sensor testing is carried out by comparing the IoT device with a standard water temperature measuring instrument.

Implementation: In this phase, the device is deployed at the location of the shrimp pond with soil construction. The protective material for the device is designed using acrylic and coated with Styrofoam to enable the device to float on the surface of the pond water. During this stage, field trials are conducted at the pond location, and water temperature data is collected. Subsequently, the accuracy of the IoT device is tested using a standard water temperature measuring instrument. This is done to determine the error value of the sensor measurements.

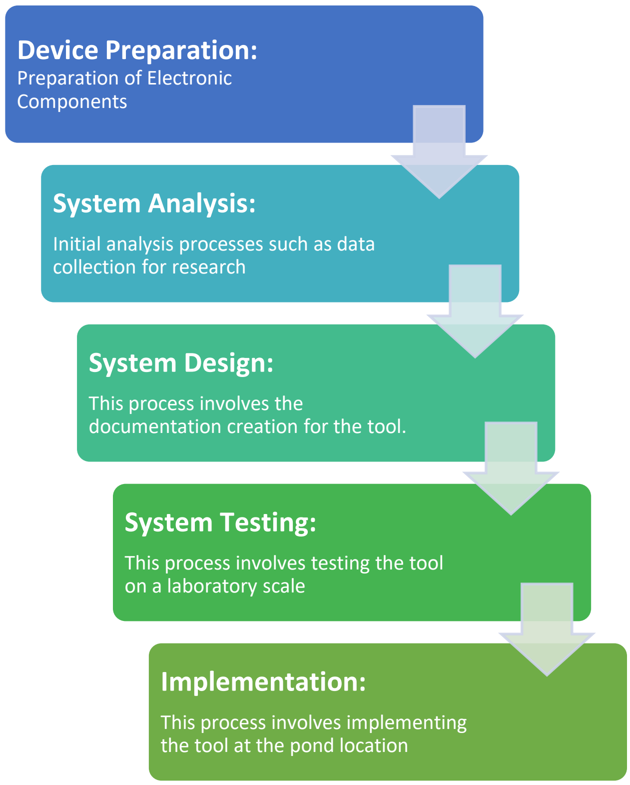


Fig. 1. Research stages

B. Proposed Modeling of Internet of Aquaculture Things (IoAT) Architecture for Traditional Shrimp Ponds

Proposed IoT Architecture Modeling for Traditional Shrimp Pond Cultivation can be seen in Fig. 2 and Fig. 3. The explanation for each level is as follows:

Aquaculture Things Layer: This is the foundational layer that serves as the object for monitoring and control. Pond water management is carried out to achieve precision in aquaculture, particularly in the cultivation of giant tiger prawns in traditional ponds.

Sensing Layer: This layer plays a role in real-time data acquisition of pond water quality. It provides input to the system to determine the pond water temperature.

Physical and Power Layer: This layer consists of microcontroller components and power sources derived from the national electricity grid (PLN). The layer receives data from sensors, which is then processed using microcontroller components. Subsequently, the data is processed by the networking layer.

Networking Layer: This layer transmits data from the sensors. It uses the IEEE 802.11 protocol for data communication between nodes and the gateway. Nodes send data to the Modem, acting as a base station (BS) connected to the internet.

Cloud Layer: This layer stores sensor data received from IoT devices temporarily in Firebase in real-time. The data from Firebase is then forwarded to MySQL for permanent storage by the Virtual Private Server based on a Linux server.

Application Layer: This layer interacts with users, providing user-sensor interactions through a responsive website platform. It displays pond water quality data in the form of visualized graphs, indicating upper and lower pond water temperatures.

User Layer: This is the final layer in this architecture. It grants access to various user levels, including farmers, government officials, academics, and exporters. This layer assists users in obtaining information related to water quality data, especially pond water temperature.

This water quality information can be used by farmers to ensure optimal growth and health for shrimp. Government officials can use this data to manage aquatic resources and make policy decisions based on actual conditions in the shrimp farming industry. Academics have access to data that can be used for scientific research in the fields of aquaculture and the environment. They can analyze long-term trends, understand the impact of environmental change on shrimp farms, and contribute to scientific knowledge. Exporters can use this information to ensure the quality of shrimp farm products before export. This involves monitoring water conditions to ensure compliance with international standards required for export.

C. Schematic Diagram and Illustration Sensor Data Transmission

This research utilizes several devices in the design process of IoT technology for tiger prawn ponds, including WeMos D1 R2, DS18B20 sensor, jumper cables, and the use of a Portable Wi-Fi. All these IoT devices will be interconnected and interact with each other. The schematic diagram of these IoT devices can be observed in Fig. 4.

The transmission of pond water temperature data will be read by the DS18B20 temperature sensor and then forwarded to the cloud server. The temperature data stored on the cloud server will be displayed through a website-based interface. Users will observe real-time pond water temperature conditions through the website interface. The stages of data transmission from the sensor to the cloud server and then displayed on the web interface can be seen in Fig. 5.

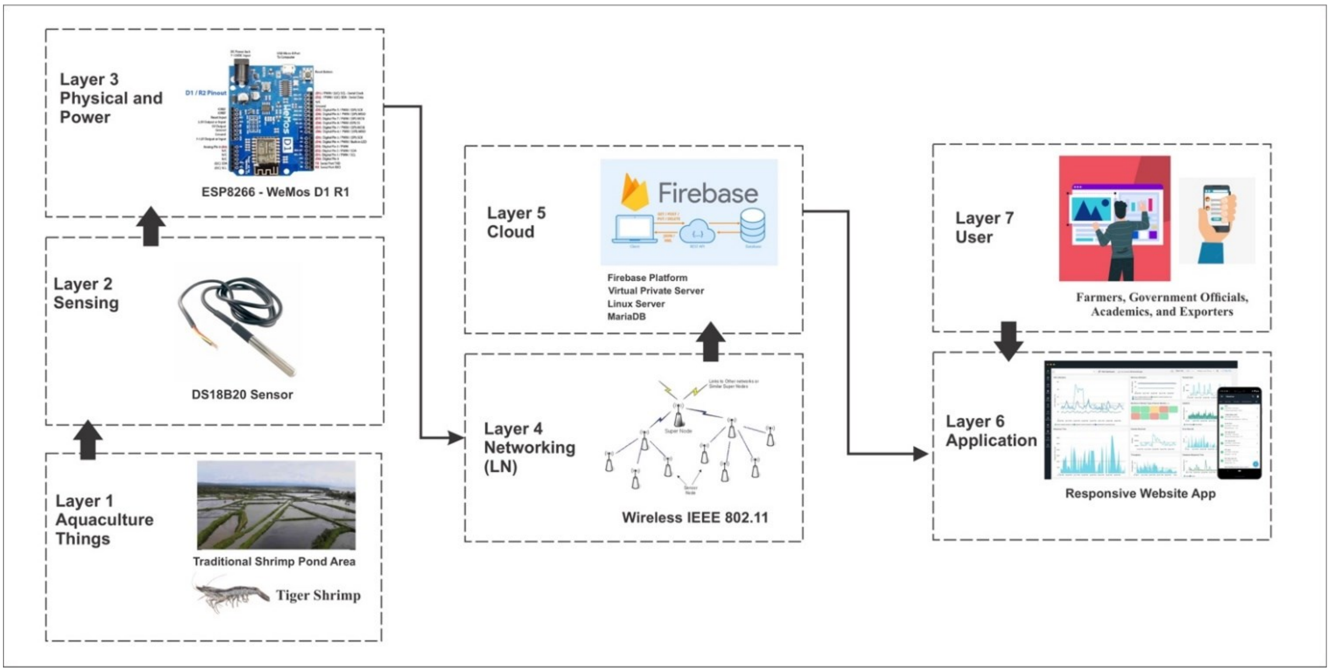


Fig. 2. Detailed Components in the Proposed Internet of Aquaculture Things (IoAT) Architecture for Traditional Shrimp Ponds

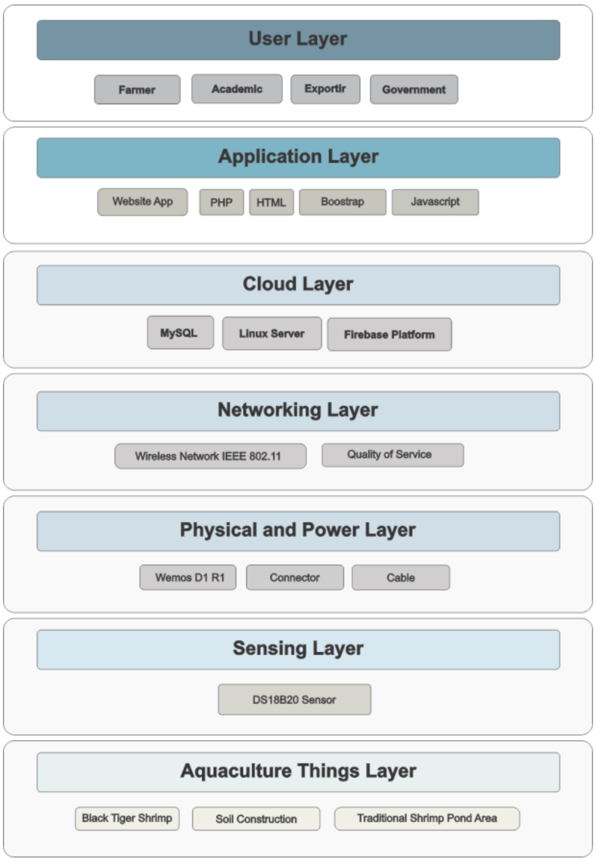


Fig. 3. Proposed Layered Architecture Modeling of the Internet of Aquaculture Things (IoAT) for Traditional Shrimp Pond Cultivation

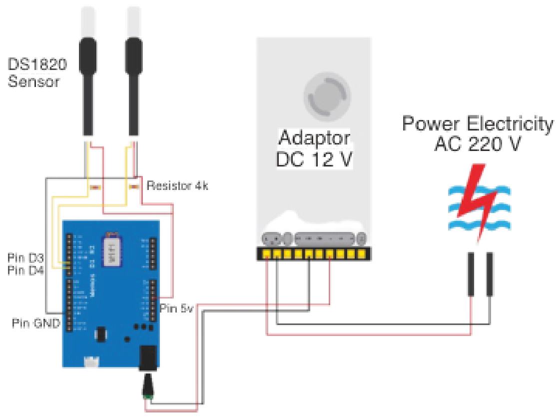


Fig. 4. Schematic Diagram

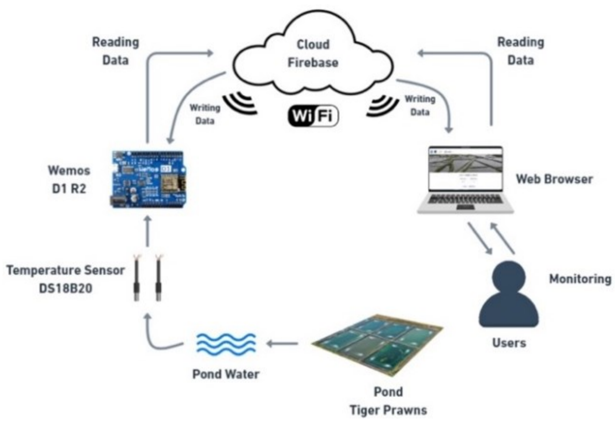


Fig. 5. Illustration Sensor Data Transmission

D. Design of IoT Device Protective Box

The IoT devices will be positioned on the surface of the pond water. Based on this, a design suitable for such conditions is necessary. In this research, Styrofoam is used as the outer protection for the IoT devices. The IoT components are placed inside an acrylic box designed in a cubic shape. The dimensions of the acrylic box are 10×20×25 cm. Subsequently, this acrylic box is equipped with an outer protector that prevents pond water or rainwater from entering it. This outer protective box is made of Styrofoam with dimensions of 14×25×39 cm. The outer protective box also has a cover to shield the IoT device from rain. The design of the device can be seen in Fig. 6.

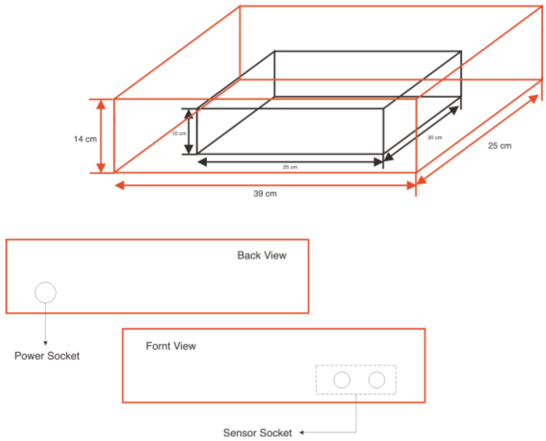


Fig. 6. IoT Design of IoT Device Protective Box

E. Layout of Device Placement in the Pond and Location of Temperature Sensor Placement

Fig. 7 illustrates the layout of the location for the earth-constructed tiger shrimp pond. This location spans 0.6 hectares and contains several plots within the area. Sensor placement is strategically positioned within the cultivation plot. These cultivation plots are deemed representative of the entire pond. The study assumes that the plots in this pond share similar water conditions. Based on this assumption, sensor placement is conducted in only one specific plot.

The placement of sensors can be seen in Fig. 8, where the temperature sensor for the upper part will be positioned near the water surface at a depth of 30 cm, while the temperature sensor for the lower part will be placed at a distance of 30 cm above the pond's bottom. The water height from the pond's bottom to the surface is 80 cm. This is done to determine the water temperature above the surface and at the bottom of the pond. The determination of sensor points is based on the water height according to the standards in traditional pond construction, which ranges from 60-80 cm. Thus, to determine the water temperature near the surface, it is placed at a depth of 30 cm from the surface, while to determine the temperature at the bottom, it is placed 30 cm above the pond's bottom. This study assumes that by placing the sensors at this 30 cm interval, it can represent the water temperature conditions above the surface and at the bottom of the pond.

Fig. 9 shows the implementation of the IoT device when placed on the surface of the pond water. The device is positioned inside Styrofoam so that it can float on the water surface. Based on Fig. 9, it can be observed that the temperature sensor's cable exits through a hole on the right side of the Styrofoam. The hole where the cable exits is covered with white glue, which serves to prevent water from entering through the cable socket.

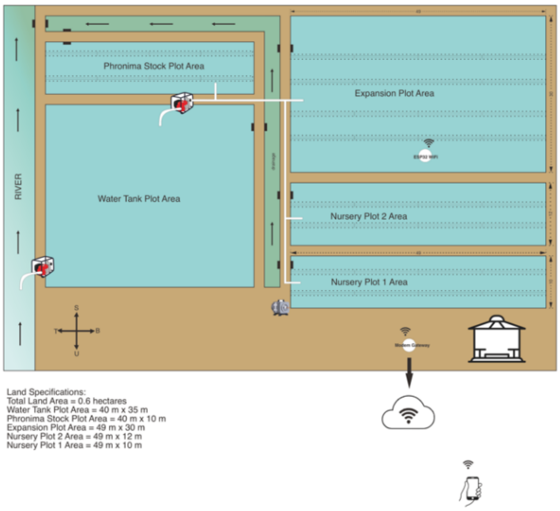


Fig. 7. Layout of Device Placement in the Pond

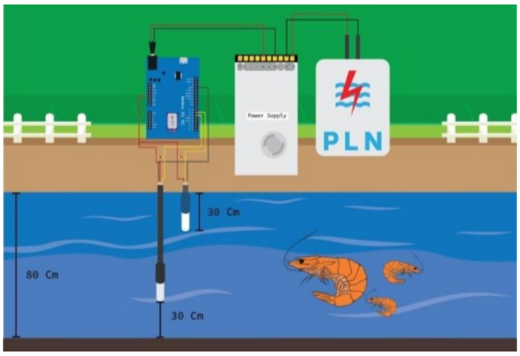


Fig. 8. Illustration of the placement sensors of upper and lower pond

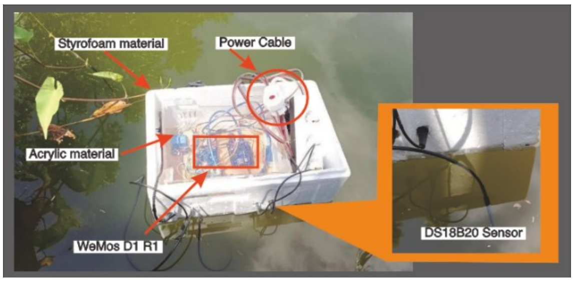


Fig. 9. Implementation of IoT device placement in the pond

III. Results and Discussion

A. *Internet of Things (IoT) Device Design*

The study has successfully developed an IoT-based system for monitoring the water temperature in ponds for the cultivation of giant tiger shrimp. The IoT system initiates by initializing the DS18B20 temperature sensor using the 1Wire library and the Dallas Temperature library to enable communication with the microcontroller. The device then identifies and connects to a wireless network. Subsequently, the device collects water temperature data from the giant tiger shrimp pond. In case the device fails to connect to the network, it will attempt reconnection. However, if the device successfully connects to the network, it will link to the Firebase Cloud. The device will then send real-time data every second to the Firebase Cloud database. Following that, the Firebase Cloud will forward the data to the VPS server. The web interface will display the received data from the VPS server. The system's flow is illustrated in Fig. 10.

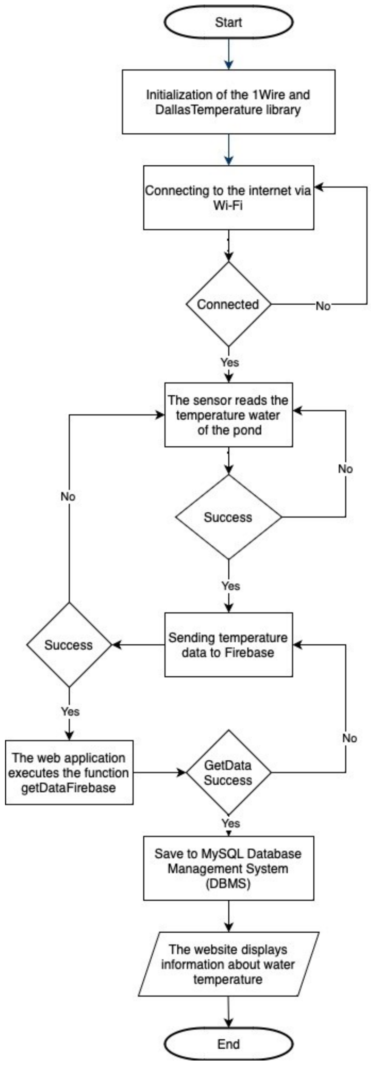


Fig. 10. Flowchart System

B. *The Code for Reading Temperature Using DS18B20 Sensor and WeMos D1 R1 Microcontroller*

```
// Initialization Library
#include <ESP8266WiFi.h>
#include <FirebaseArduino.h>
#include <OneWire.h>
#include <DallasTemperature.h>

// Declaration Variable and Constants value
#define FIREBASE_HOST ""
#define FIREBASE_AUTH ""
#define WIFI_SSID ""
#define WIFI_PASSWORD ""
#define ONE_WIRE_BUS_ATAS   : Pin
#define ONE_WIRE_BUS_BAWAH  : Pin
var suhuAirAtas, suhuAirBawah        : float

// Initialization Network
READ: WIFI_SSID, WIFI_PASSWORD, FIREBASE_HOST, FIREBASE_AUTH

// Connect to Wi-Fi network
WiFi.begin(WIFI_SSID, WIFI_PASSWORD)
PRINT "Connecting"
WHILE (WiFi.status() != WL_CONNECTED)
    PRINT "."
ENDWHILE
PRINT "Connected: " PRINTLN WiFi.localIP
```

```
// Initialize Firebase
Firebase.begin(FIREBASE_HOST, FIREBASE_AUTH)

// Request and store temperature values
TopWater.requestTemperatures()
TopWatertemperature = TopWater.getTempCByIndex(0)
PRINT " Top Water temperature: "
PRINTLN TopWatertemperature
BottomWater.requestTemperatures()
BottomWatertemperature = BottomWater.getTempCByIndex(0)
PRINT " Bottom Water temperature: "
PRINTLN BottomWatertemperature

// Upload data to Firebase
Firebase.setFloat("Top_Water ", TopWatertemperature)
Firebase.setFloat("Bottom_Water ", BottomWatertemperature)

// Check for upload failure
IF(Firebase.failed()) THEN
    PRINT "Setting / Number Failed: "
    PRINTLN Firebase.error()
ENDIF
```

Initialization Library: The ESP8266WiFi library is used for ESP8266 module communication with a Wi-Fi network. The Firebase Arduino library is used to integrate Firebase functionality into the system. The OneWire library facilitates communication with OneWire protocol devices. The Dallas Temperature Library allows temperature measurements using temperature sensors from Dallas Semiconductor.

Declaration Variable and Constants values: Several constant variables are declared using the preprocessor directive #define, including FIREBASE_HOST, FIREBASE_AUTH, WIFI_SSID, WIFI_PASSWORD, and pin definitions for ONE_WIRE_BUS_UP and ONE_WIRE_BUS_BOTTOM. Two variables, TopWatertemperature and BottomWatertemperature, are declared as floats to store temperature data.

Initialization Network: The system reads the values for WIFI_SSID, WIFI_PASSWORD, FIREBASE_ HOST, and FIREBASE_AUTH. Connect to Wi-Fi network: The system tries to connect to the specified Wi-Fi network. The code prints the connection status and local IP address once the device is connected.

Initialize Firebase: Firebase is started using the specified FIREBASE_HOST and FIREBASE_AUTH credentials. Request and store temperature values: Upper and lower water temperature values are requested and stored. The code prints the obtained temperature value.

Upload data to Firebase: The temperature values are then uploaded to the Firebase database. Check for upload failure: If upload failure occurs, an error message will be printed.

C. Website User Interface for Monitoring Pond Water Temperature

Fish farmers can view real-time water temperature conditions through the website. The web interface offers several features, including displaying pond water temperature as shown in Fig. 11. Another feature is to show the log data of temperature sensor readings, as indicated in Fig. 12. The next feature is to display a line graph of real-time recorded water temperature conditions, as shown in Fig. 13.

Fig. 12 displays real-time observations of the pond water temperature. The observations indicate that the pond water conditions during testing are within the normal range, in accordance with the temperature standards of approximately 28-31°C. Changes in this data will occur if the surrounding weather conditions change, as shown in Fig. 13, where the temperature log indicates the highest value reached 32.31°C, while the lowest water temperature is 27.69 °C. This indicates that there has been a temperature change due to the weather conditions around the pond.

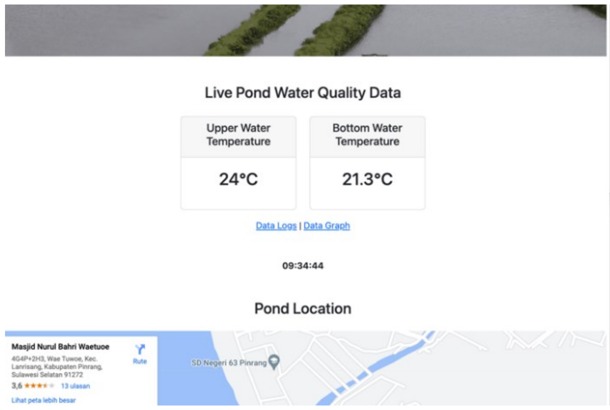
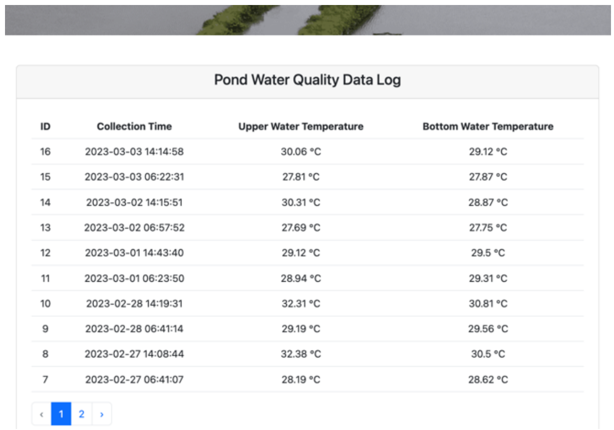


Fig. 11. User interface website



Pond Water Quality Data Log

ID	Collection Time	Upper Water Temperature	Bottom Water Temperature
16	2023-03-03 14:14:58	30.06 °C	29.12 °C
15	2023-03-03 06:22:31	27.81 °C	27.87 °C
14	2023-03-02 14:15:51	30.31 °C	28.87 °C
13	2023-03-02 06:57:52	27.69 °C	27.75 °C
12	2023-03-01 14:43:40	29.12 °C	29.5 °C
11	2023-03-01 06:23:50	28.94 °C	29.31 °C
10	2023-02-28 14:19:31	32.31 °C	30.81 °C
9	2023-02-28 06:41:14	29.19 °C	29.56 °C
8	2023-02-27 14:08:44	32.38 °C	30.5 °C
7	2023-02-27 06:41:07	28.19 °C	28.62 °C

Fig. 12. Log data monitoring

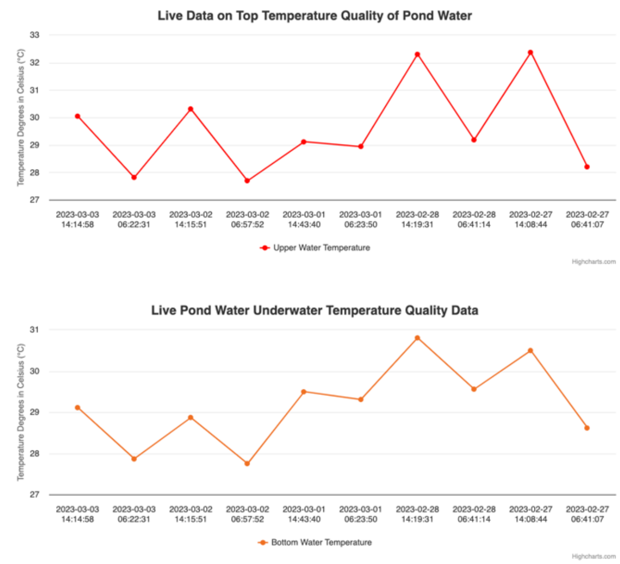


Fig. 13. Graphic display of pond water temperature data

Table I shows the results of data collection from the DS18B20 temperature sensor in 16 iterations. Based on Table I, it is evident that there is a fluctuation in water temperature, particularly in iteration 10, where there is an increase in water temperature to 32.31°C near the surface and 30.81°C near the bottom of the pond. The cause of this temperature rise is attributed to the hot weather conditions surrounding the pond. However, in iteration 13, there is a decrease in water temperature due to cold weather around the pond, registering a value of 27.69°C.

TABLE I. COLLECTION OF DATA RESULTS

Iteration	Testing Time	Upper Temperature (°C)	Lower Temperature (°C)
1	2023-02-24 06:46:50	28.31	28.81
2	2023-02-24 14:17:37	31.13	30.5
3	2023-02-25 06:54:50	29.12	29.62
4	2023-02-25 14:33:50	31.06	30.69
5	2023-02-26 06:39:55	29.12	29.62
6	2023-02-26 14:26:58	29.19	29.62
7	2023-02-27 06:41:07	28.19	28.62
8	2023-02-27 14:08:44	32.38	30.5
9	2023-02-28 06:41:14	29.19	29.56
10	2023-02-28 14:19:31	32.31	30.81
11	2023-03-01 06:23:50	28.94	29.31
12	2023-03-01 14:43:40	29.12	29.5
13	2023-03-02 06:57:52	27.69	27.75
14	2023-03-02 14:15:51	30.31	28.87
15	2023-03-03 06:22:31	27.81	27.87
16	2023-03-03 14:14:58	30.06	29.12

D. Testing the Error and Accuracy of DS18B20 Sensor Measurements

The testing of the DS18B20 temperature sensor aims to determine the level of accuracy and the extent of temperature data error obtained from the sensor. Measurements are conducted by comparing the DS18B20 temperature sensor with a standard water temperature measuring device. Both the DS18B20 sensor and the standard water temperature measuring device are immersed in the same water, and then the temperature measurement process is carried out. The temperature readings from the sensor will be displayed on the website's data log.

The results of the DS18B20 temperature sensor readings are presented in Table II and Table III. To determine the difference in sensor measurements when measuring water temperature, the equation (1) is employed. Based on the difference measurement results from equation (1), further steps are taken to assess semantic errors using the equation (2). Systematic errors are a type of error that occurs consistently and can be identified in each measurement or experiment. In addition to measuring errors, this research also conducts an accuracy assessment of the sensor using equation (3).

$$error = |X - Xi| \quad (1)$$

$$\%error = |(X - Xi) / * 100\%| \quad (2)$$

$$Accuracy = (100 - \%error) \quad (3)$$

In equation (1), there are variables X, representing the temperature measured using the standard temperature measuring device. Subsequently, variable Xi represents the measured values using the DS18B20 sensor. As for the semantic error value, it is denoted by the variable %error.

Based on Table II and Table III, the level of error and accuracy of DS18B20 sensor measurements reached an error value of 5.26%, with an accuracy of 94.734%. In another study [58] reported an error of 0.29%; [59] achieved a 5% error; [60] reported a 0.2% error; [61] error is 0.829%; [62] had a 3.00% error with accuracy below 85%. In the study [63], the sensor accuracy ranged from 95% to 99%. Furthermore, in the research [58] accuracy was reported to be 99.71% and 99.83%. Based on this comparison, it is evident that the average measurement error rate of the DS18B20 sensor ranges from 0.05% to 0.5%, with accuracy levels ranging from 85% to 99%.

In the research that we have conducted, the measurement results of the DS18B20 sensor showed a temperature range of 28-31°C. Research conducted by [58] showed water temperature values ranging from 20-60°C. Other studies achieved temperatures of 26.2°C-27°C [64]. Subsequently, the research [65] showed temperatures of 25 - 30 °C; [66] 23.89°C-32.22°C. This indicates that the temperature readings of the DS18B20 sensor under various conditions in different research locations are within the range of 20-31°C.

The research we conducted also utilized the ESP8266 microcontroller, aligning with several previous studies [67]–[76] that also used the same microcontroller as the central data sensor management. Previous studies have also utilized cloud technology [77]–[81] for cloud-based data storage and monitoring through a website interface [57]. Based on previous research, there is compatibility in the technology used in this study, demonstrating that the implementation of IoT for monitoring the water temperature quality of ponds is a continuously evolving aspect, adaptable to the needs of other observed parameters such as pH, water oxygen levels, water height, and salinity.

TABLE II. COMPARISON OF THERMOMETER WITH DS18B20 FOR WATER UPPER TEMPERATURE MEASUREMENT

Test	Thermometer (°C)	Upper Temperature (°C)	Error	Error (%)	Accuracy (%)
1	27.4	28.31	0.91	3.32	96.68
2	32.4	31.13	1.27	3.92	96.08
3	31.2	29.12	2.08	6.67	93.33
4	28.3	31.06	2.76	9.75	90.25
5	30.4	29.12	1.28	4.21	95.79
6	29.6	29.19	0.41	1.39	98.61
7	26	28.19	2.19	8.42	91.58
8	30	32.38	2.38	7.93	92.07
9	31.2	29.19	2.01	6.44	93.56
10	28.4	32.31	3.91	13.77	86.23
Rata-rata error, % error and accuracy			1.92	6.58	93.418

TABLE III. COMPARISON OF THERMOMETER WITH DS18B20 FOR WATER BOTTOM TEMPERATURE MEASUREMENT

Test	Thermometer (°C)	Lower Temperature (°C)	Error	Error (%)	Accuracy (%)
1	27.4	28.81	1.41	5.15	94.85
2	32.4	30.5	1.9	5.86	94.14
3	31.2	29.62	1.58	5.06	94.94
4	28.3	30.69	2.39	8.45	91.55
5	30.4	29.62	0.78	2.57	97.43
6	29.6	29.62	0.02	0.07	99.93
7	26	28.62	2.62	10.08	89.92
8	30	30.5	0.5	1.67	98.33
9	31.2	29.56	1.64	5.26	94.74
10	28.4	30.81	2.41	8.49	91.51
Rata-rata error, % error and accuracy			1.53	5.26	94.734

IV. CONCLUSION

This investigation has effectively harnessed the capabilities of IoT devices, specifically employing DS18B20 temperature sensors integrated with WeMos D1 R2 controllers, to monitor water temperatures in conventional shrimp ponds. The system demonstrated significant accuracy, with measurements at 93.42% near the water's surface and 94.74% at the pond's bottom, alongside a sensor error rate of 5.26%. The advancement of this study also lies in its real-time temperature monitoring through a user-friendly web interface.

Despite these achievements, the study acknowledges certain limitations, including a sensor error margin that necessitates reduction and an accuracy level that aspires to reach the 99% benchmark. Consequently, future work is suggested to enhance the observational precision of sensor data and to expand the monitoring network by integrating multi-path routing in Wireless Sensor Networks (WSN). Further research should also consider additional water quality metrics such as pH, oxygen levels, and salinity. The potential application of Artificial Intelligence (AI) in subsequent studies promises to refine aquaculture practices through the analysis of water quality and meteorological time-series data, stored in the cloud for advanced predictive insights.

ACKNOWLEDGMENT

The fruition of this research owes much to the collective contributions of numerous individuals and organizations. We extend our profound appreciation to the Directorate of Research, Technology, and Community Service Indonesia for their financial support and to all collaborators whose dedication made this work possible.

REFERENCES

[1] M. H. Fattah and S. Rahbiah, "Developing detoxification and purification technologies of ponds with pesticide residue for organic tiger shrimp farming development," *Earth Environ. Sci.*, vol. 260, no. 1, 2019, doi: 10.1088/1755-1315/260/1/012106.

[2] A. Mustafa and E. Ratnawati, "Dominant factors that effect on the productivity of brackishwater ponds in Pinrang Regency, South Sulawesi," *Jurnal Riset Akuakultur*, vol. 2, no. 1, pp. 117-133, 2007.

[3] M. H. Fattah, S. R. Busaeri, and A. Munandar, "Survival Rate and Quality of Phronima Suppa (Phronima sp) Zoea with the Cryptobiosis Application," *Earth Environ. Sci.*, vol. 391, no. 1, 2019, doi: 10.1088/1755-1315/391/1/012076.

[4] M. H. Fattah, S. Rahbiah, B. Modding, and S. Marhamah, "Feasibility and vulnerability of the preserved shrimp eco-farming park of Pinrang district," *AACL Bioflux*, vol. 13, no. 6, pp. 3626–3636, 2020.

[5] Y. R. Alfiansah, J. Harder, M. J. Slater, and A. Gärdes, "Addition of Molasses Ameliorates Water and Bio-Floc Quality in Shrimp Pond Water," *Trop. Life Sci. Res.*, vol. 33, no. 1, pp. 121–141, 2022, doi: 10.21315/tlsr2022.33.1.8.

[6] N. Wannee and T. Samanchuen, "A Flexible Water Monitoring System for Pond Aquaculture," *2022 International Conference on Digital Government Technology and Innovation (DGTi-CON)*, pp. 91-95, 2022, doi: 10.1109/DGTi-CON53875.2022.9849186.

[7] V. A. Wardhany, H. Yuliandoko, - Subono, M. U. Harun A, and I. G. P. Astawa, "Smart System and Monitoring of Vanammei Shrimp Ponds," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 11, no. 4, p. 1366, 2021, doi: 10.18517/ijaseit.11.4.8557.

[8] T. D. Chuyen, D. D. Nguyen, N. C. Cuong, and V. V. Thong, "Design and manufacture control system for water quality based on IoT technology for aquaculture in the Vietnam," *Bull. Electr. Eng. Informatics*, vol. 12, no. 4, pp. 1893–1900, 2023, doi: 10.11591/eei.v12i4.5180.

[9] H. F. Hawari and M. A. Hazwan, "Development of Iot Monitoring System For Aquaculture Application," *2022 International Conference on Green Energy, Computing and Sustainable Technology (GECOST)*, pp. 330-334, 2022, doi: 10.1109/GECOST55694.2022.10010661.

[10] M. I. Bachtiar, R. Hidayat, and R. Anantama, "Internet of Things (IoT) Based Aquaculture Monitoring System," *MATEC Web*, vol. 372, 2022, doi: 10.1051/matecconf/202237204009.

[11] T. J. Alam, A. A. S. Bin Hayder, A. F. Apu, M. H. Al Banna, and M. Sazzadur Rahman, "IoT Based Biofloc Aquaculture Monitoring System," In *Proceedings of the Fourth International Conference on Trends in Computational and Cognitive Engineering: TCCE 2022*, pp. 99-112, 2023, doi: 10.1007/978-981-19-9483-8_9.

[12] G. R. Kanagachidambaresan, "IoT-Based Shrimp Farming," In *Internet of Things Using Single Board Computers: Principles of IoT and Python Programming*, pp. 265-279, 2022, doi: 10.1007/978-1-4842-8108-6_10.

[13] K. Wójcicki, M. Biegańska, B. Paliwoda, and J. Górna, "Internet of Things in Industry: Research Profiling, Application, Challenges and Opportunities-A Review," *Energies*, vol. 15, no. 5, p. 1806, 2022, doi: 10.3390/en15051806.

[14] S. Budijono and Felita, "Smart Temperature Monitoring System Using ESP32 and DS18B20," in *Earth and Environmental Science*, vol. 794, no. 1, 2021, doi: 10.1088/1755-1315/794/1/012125.

[15] M. Komarudin, H. D. Septama, T. Yulianti, A. Yudamson, J. Hendri, and M. A. D. Arafat, "Multi node sensors for water quality monitoring towards precision aquaculture," in *Earth and Environmental Science*, vol. 739, no. 1, 2021, doi: 10.1088/1755-1315/739/1/012026.

[16] Z. Zhang *et al.*, "Development of remote monitoring system for aquaculture water quality based on Internet of Things," in *Materials Science and Engineering*, vol. 768, no. 5, 2020, doi: 10.1088/1757-899X/768/5/052033.

[17] C. J. Den Ouden, P. S. Wills, L. Lopes, J. Sanderson, and B. Ouyang, "Evolution of the Hybrid Aerial Underwater Robotic System (HAUCS) for Aquaculture: Sensor Payload and Extension Development," *Vehicles*, vol. 4, no. 2, pp. 390–408, 2022, doi: 10.3390/vehicles4020023.

[18] L. V. Q. Danh, D. V. M. Dung, T. H. Danh, and N. C. Ngon, "Design and Deployment of an IoT-Based Water Quality Monitoring System for Aquaculture in Mekong Delta," *Int. J. Mech. Eng. Robot. Res.*, pp. 1170–1175, 2020, doi: 10.18178/ijmerr.9.8.1170-1175.

[19] Z. Shareef and S. R. N. Reddy, "Design and Development of IoT-Based Framework for Indian Aquaculture," in *Intelligent Communication, Control and Devices*, pp. 195–201, 2020.

[20] F. Liu and P. Wang, "Aquaculture environment monitoring system based on Internet of Things," In *Second International Conference on Green Communication, Network, and Internet of Things (CNIoT 2022)*, vol. 12586, pp. 202-207, 2023, doi: 10.1117/12.2668766.short.

[21] M. F. Taha *et al.*, "Recent Advances of Smart Systems and Internet of Things (IoT) for Aquaponics Automation: A Comprehensive Overview," *Chemosensors*, vol. 10, no. 8, p. 303, 2022, doi: 10.3390/chemosensors10080303.

[22] F. O'Donncha and J. Grant, "Precision Aquaculture," *IEEE Internet Things Mag.*, vol. 2, no. 4, pp. 26–30, 2019, doi: 10.1109/IOTM.0001.1900033.

[23] C.-H. Chen, Y.-C. Wu, J.-X. Zhang, and Y.-H. Chen, "IoT-Based Fish Farm Water Quality Monitoring System," *Sensors*, vol. 22, no. 17, 2022, doi: 10.3390/s22176700.

[24] W. J. Hong *et al.*, "Water quality monitoring with arduino based sensors," *Environ.*, vol. 8, no. 1, pp. 1–15, 2021, doi: 10.3390/environments8010006.

[25] M. I. Dzulqornain, M. U. H. Al Rasyid, and S. Sukaridhoto, "Design and Development of Smart Aquaculture System Based on IFTTT Model and Cloud Integration," *MATEC*, vol. 164, 2018, doi: 10.1051/matecconf/201816401030.

[26] M. Niswar *et al.*, "IoT-based Water Quality Monitoring System for Soft-Shell Crab Farming," in *2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS)*, pp. 6–9, 2018, doi: 10.1109/IOTAIS.2018.8600828.

[27] B. J. Kim and K. J. Shin, "Development of Smart Fish Farming System Based on IoT Using Wasted Warm Water Energy," *J. Inst. Control. Robot. Syst.*, vol. 24, no. 2, pp. 155–163, 2018, doi: 10.5302/J.ICROS.2018.17.0214.

[28] Z. Zhang, W. Mao, C. Li, D. Wang, Y. Zhang, and Q. Liu, "The design and software development of remote monitoring system for aerator," *Mater. Sci. Eng.*, vol. 768, no. 5, 2020, doi: 10.1088/1757-899X/768/5/052104.

[29] N. A. Ubina *et al.*, "Digital twin-based intelligent fish farming with Artificial Intelligence Internet of Things (AIoT)," *Smart Agric. Technol.*, vol. 5, p. 100285, 2023, doi: 10.1016/j.atech.2023.100285.

[30] H. Li, "Aquiculture remote monitoring system based on IoT Android platform," *Nongye Gongcheng Xuebao/Transactions Chinese Soc. Agric. Eng.*, vol. 29, no. 13, pp. 175–181, 2013, doi: 10.3969/j.issn.1002-6819.2013.13.023.

[31] M. S. Munir, I. S. Bajwa, and S. M. Cheema, "An intelligent and secure smart watering system using fuzzy logic and blockchain," *Comput. Electr. Eng.*, vol. 77, pp. 109–119, 2019, doi: 10.1016/j.compeleceng.2019.05.006.

[32] R. K. Jain, B. Gupta, M. Ansari, and P. P. Ray, "IOT Enabled Smart Drip Irrigation System Using Web/Android Applications," *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, pp. 1-6, 2020, doi: 10.1109/ICCCNT49239.2020.9225345.

[33] P. S. Sneha and V. S. Rakesh, "Automatic monitoring and control of shrimp aquaculture and paddy field based on embedded system and IoT," *2017 International Conference on Inventive Computing and Informatics (ICICI)*, pp. 1085-1089, 2017, doi: 10.1109/ICICI.2017.8365307.

[34] I. M. Hakimi and Z. Jamil, "Development of Water Quality Monitoring Device Using Arduino UNO," in *Materials Science and Engineering*, vol. 1144, no. 1, 2021, doi: 10.1088/1757-899x/1144/1/012064.

[35] R. Quintero, J. Parra, and F. Felix, "Water quality assurance in aquaculture ponds using Machine Learning and IoT techniques," in *2022 IEEE Mexican International Conference on Computer Science (ENC)*, pp. 1–6, 2022, doi: 10.1109/ENC56672.2022.9882920.

[36] A. Mauliddin, "Design of Monitoring of Water Temperature and pH of Vaname Shrimp Hatchery Ponds Based on Android," *J. Jartel J. Jar. Telekomun.*, vol. 6, no. 1, pp. 9–16, 2018, doi: 10.33795/jartel.v6i1.129.

[37] B. Shi, V. Sreeram, D. Zhao, S. Duan, and J. Jiang, "A wireless sensor network-based monitoring system for freshwater fishpond aquaculture," *Biosyst. Eng.*, vol. 172, pp. 57–66, 2018, doi: 10.1016/j.biosystemseng.2018.05.016.

[38] L. Shu and X. Wen, "An aquaculture monitoring system based on NB-IoT," in *2021 33rd Chinese Control and Decision Conference (CCDC)*, pp. 5620–5624, 2021, doi: 10.1109/CCDC52312.2021.9601877.

[39] B. Ngom, M. Diallo, B. Gueye, and N. Marilleau, "LoRa-based Measurement Station for Water Quality Monitoring: Case of Botanical Garden Pool," in *SAS*, pp. 1–4, 2019, doi: 10.1109/SAS.2019.8705986.

[40] D. Sousa, D. Hernandez, F. Oliveira, M. Luís, and S. Sargento, "A Platform of Unmanned Surface Vehicle Swarms for Real Time Monitoring in Aquaculture Environments," *Sensors*, vol. 19, no. 21, 2019, doi: 10.3390/s19214695.

[41] I. K. A. Enriko, F. N. Gustiyana, M. Misbahuddin, and I. G. B. Astawa, "Implementation of Temperature and Humidity Monitoring System Using LoRaWAN for Pharmaceutical Industry," In *First Mandalika International Multi-Conference on Science and Engineering 2022, MIMSE 2022 (Informatics and Computer Science)(MIMSE-IC-2022)*, pp. 234-244, 2022.

[42] R. Adriman, M. Fitria, A. Afdhal, and A. Y. Fernanda, "An IoT-Based System for Water Quality Monitoring and Notification System of Aquaculture Prawn Pond," in *COMNETSAT*, pp. 356–360, 2022, doi: 10.1109/COMNETSAT56033.2022.9994388.

[43] M. Dharmawan, L. D. Sari, J. P. Gunawan, E. Antriyandarti, and A. Duong, "Gazebo Semar: An Android-based Farmer Education Platform for Agricultural Waste Management," *J. Ilm. Tek. Elektro Komput. dan Inform.*, vol. 9, no. 1, pp. 174–184, 2023, doi: 10.26555/jiteki.v9i1.25757.

[44] E. P. Harahap, M. A. Ngadi, U. Rahardja, F. R. Azhari, and K. Zelina, "Internet of things based humidity control and monitoring system," *ILKOM Jurnal Ilmiah*, vol. 13, no. 2, pp. 175–186, 2021, doi: 10.33096/ilkom.v13i2.852.175-186.

[45] G. V. R. Kameshwar Rao, T. J. Dhivya Shrilaa, I. Akash, and G. Gugapriya, "Aquaculture Monitoring System Using Internet of Things," in *Intelligent Cyber Physical Systems and Internet of Things*, pp. 11–29, 2023.

[46] P. Sun and Y. Chen, "Aquiculture Remote Monitoring System Based on Internet of Things," *2019 International Conference on Robots & Intelligent System (ICRIS)*, pp. 187-190, 2019, doi: 10.1109/ICRIS.2019.00056.

[47] S. Saha, R. Hasan Rajib, and S. Kabir, "IoT Based Automated Fish Farm Aquaculture Monitoring System," in *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)*, pp. 201–206, 2018, doi: 10.1109/ICISET.2018.8745543.

[48] K. S. Niraja, "Survey on internet of things based prototype design for aquaculture using machine learning," in *6th Smart Cities Symposium (SCS 2022)*, pp. 132–135, 2022, doi: 10.1049/icp.2023.0363.

[49] Z. Zhang *et al.*, "Development of remote monitoring system for aquaculture water quality based on Internet of Things," in *Materials Science and Engineering*, vol. 768, no. 5, 2020, doi: 10.1088/1757-899X/768/5/052033.

[50] K.-L. T. Kun-Lin Tsai, L.-W. C. Kun-Lin Tsai, L.-J. Y. Li-Woei Chen, H.-J. S. Li-Jun Yang, and H.-W. C. Hung-Jr Shiu, "IoT based Smart Aquaculture System with Automatic Aerating and Water Quality Monitoring," *J. Internet Technol.*, vol. 23, no. 1, pp. 179–186, 2022, doi: 10.53106/160792642022012301018.

[51] U. Acar *et al.*, "Designing An IoT Cloud Solution for Aquaculture," in *2019 Global IoT Summit (GIoTS)*, pp. 1–6, 2019, doi: 10.1109/GIOTS.2019.8766428.

[52] Y. Irawan, H. Fonda, E. Sabna, and A. Febriani, "Intelligent Quality Control of Shrimp Aquaculture Based On Real-Time System and IoT Using Mobile Device," *Int. J. Eng. Trends Technol.*, vol. 69, no. 4, pp. 49–56, 2021, doi: 10.14445/22315381/IJETT-V69I4P208.

[53] J.-Y. Lin, H.-L. Tsai, and W.-H. Lyu, "An Integrated Wireless Multi-Sensor System for Monitoring the Water Quality of Aquaculture," *Sensors*, vol. 21, no. 24, 2021, doi: 10.3390/s21248179.

[54] H. Zhang and F. Gui, "The Application and Research of New Digital Technology in Marine Aquaculture," *J. Mar. Sci. Eng.*, vol. 11, no. 2, 2023.

[55] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," *IEEE Commun. Surv. Tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015, doi: 10.1109/COMST.2015.2444095.

[56] A. Malik and H. Om, "Cloud Computing and Internet of Things Integration: Architecture, Applications, Issues, and Challenges," in *Sustainable Cloud and Energy Services*, pp. 1–24, 2018.

[57] S. K. N. El-deen, H. Elborai, H. E. M. Sayour, and A. Yahia, "Wireless Sensor Network Based Solution for Water Quality Real-Time Monitoring," *Egypt. J. Solids*, vol. 41, no. 1, pp. 49–62, 2018, doi: 10.21608/ejs.2018.148253.

[58] Junaidi *et al.*, "Measurement of Physical Parameters of Water Quality in Real-Time Based on Arduino," in *Journal of Physics*, vol. 1751, no. 1, 2021, doi: 10.1088/1742-6596/1751/1/012067.

[59] I. M. Hakimi and Z. Jamil, "Development of Water Quality Monitoring Device Using Arduino UNO," *Mater. Sci. Eng.*, vol. 1144, no. 1, 2021, doi: 10.1088/1757-899X/1144/1/012064.

[60] D. Paz, H. Bedon, and E. Saettone, "Design of a water quality monitoring station for use in precision aquaculture with IoT

technology," *Turkish Online J. Qual. Inq.*, vol. 12, no. 7, pp. 13147–13153, 2021.

[61] H. R. Fajrin, M. R. Ilahi, B. S. Handoko, and I. P. Sari, "Body temperature monitoring based on telemedicine," *J. Phys. Conf. Ser.*, vol. 1381, no. 1, 2019, doi: 10.1088/1742-6596/1381/1/012014.

[62] R. A. Koestoer, Y. A. Saleh, I. Roihan, and Harinaldi, "A simple method for calibration of temperature sensor DS18B20 waterproof in oil bath based on Arduino data acquisition system," in *AIP Conference Proceedings*, vol. 2062, 2019, doi: 10.1063/1.5086553.

[63] X. Zhao, W. Li, L. Zhou, G. B. Song, Q. Ba, and J. Ou, "Active thermometry based DS18B20 temperature sensor network for offshore pipeline scour monitoring using K -means clustering algorithm," *Int. J. Distrib. Sens. Networks*, vol. 9, no. 6, p. 852090, 2013, doi: 10.1155/2013/852090.

[64] Sujito *et al.*, "Water Quality Monitoring System in Guorami Fish Cultivation Based on Microcontroller," *Proc. 4th Forum Res. Sci. Technol.*, vol. 7, pp. 119–122, 2021, doi: 10.2991/ahe.k.210205.022.

[65] W. Boonsong, "Embedded Wireless Dissolved Oxygen Monitoring Based on Internet of Things Platform," *J. Commun.*, pp. 363–368, 2021, doi: 10.12720/jcm.16.9.363-368.

[66] H. F. Hawari and M. A. Hazwan, "Development of Iot Monitoring System for Aquaculture Application," *2022 Int. Conf. Green Energy, Comput. Sustain. Technol. GECOST 2022*, pp. 330–334, 2022, doi: 10.1109/GECOST55694.2022.10010661.

[67] B. Siswanto, Y. Dani, D. Morika, and B. Mardiyana, "A simple dataset of water quality on aquaponic fish ponds based on an internet of things measurement device," *Data in Brief*, vol. 48, p. 109248, 2023, doi: 10.1016/j.dib.2023.109248.

[68] A. K. M. Masum, "Implementation of Internet of Things (IoT)-based Aquaculture System Using Machine Learning Approaches," *Comput. Sci. J. Mold.*, vol. 29, no. 3, pp. 320–329, 2021.

[69] P. V. Kumar, "Aquaculture monitoring system using machine learning," *ARPN J. Eng. Appl. Sci.*, vol. 18, no. 14, pp. 1700–1706, 2023, doi: 10.59018/0723211.

[70] S. Zakaria *et al.*, "Nature Driven IoT Based Automation of Aquaponic System," in *Lecture Notes in Mechanical Engineering*, pp. 555–562, 2021.

[71] G. Long, "Design of an aquaculture detection system based on internet of things," *Int. J. Simul. Syst. Sci. Technol.*, vol. 17, no. 31, 2016.

[72] G. Y. Sriram and N. B. Sai Shibu, "Design and Implementation of Automated Aquaponic System with Real-time Remote Monitoring," in *2021 Advanced Communication Technologies and Signal Processing (ACTS)*, pp. 1–6, 2021, doi: 10.1109/ACTS53447.2021.9708396.

[73] W. Boonsong, "Embedded Wireless Dissolved Oxygen Monitoring Based on Internet of Things Platform," *J. Commun.*, vol. 16, no. 9, pp. 363–368, 2021, doi: 10.12720/jcm.16.9.363-368.

[74] M. K. A. Chy, A. K. M. Masum, M. E. Hossain, M. G. R. Alam, S. I. Khan, and M. S. Alam, "A Low-Cost Ideal Fish Farm Using IoT: In the Context of Bangladesh Aquaculture System," in *Lecture Notes in Networks and Systems*, vol. 89, 2020, pp. 1273–1283.

[75] J. Duangwongsa, T. Ungsethaphand, P. Akaboot, S. Khamjai, and S. Unankard, "Real-time Water Quality Monitoring and Notification System for Aquaculture," in *Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunication Engineering*, pp. 9–13, 2021, doi: 10.1109/ECTIDAMTNCON51128.2021.9425744.

[76] A. K. M. Masum, M. Shahin, M. K. A. Chy, S. I. Khan, A. Shan-A-Alahi, and M. G. R. Alam, "Design and Implementation of IoT based Ideal Fish Farm in the Context of Bangladesh Aquaculture System," in *ICASERT*, pp. 1–6, 2019, doi: 10.1109/ICASERT.2019.8934736.

[77] S. A. Hashmi, C. F. Ali, and S. Zafar, "Internet of things and cloud computing-based energy management system for demand side management in smart grid," *Int. J. Energy Res.*, vol. 45, no. 1, pp. 1007–1022, 2021, doi: 10.1002/er.6141.

[78] N. Ismail *et al.*, "Smart irrigation system based on internet of things (IoT)," in *Journal of Physics*, vol. 1339, no. 1, p. 012012, 2019, doi: 10.1088/1742-6596/1339/1/012012.

[79] A. K. Sharma and L. M. Saini, "IoT based Diagnosing Myocardial Infarction through Firebase Web Application," in *2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA)*, pp. 190–195, 2019, doi: 10.1109/ICECA.2019.8822150.

[80] D. P. Alamsyah, Y. Ramdhani, S. R. Rhamadhan, and L. Susanti, "Application of IoT and Cloud Storage in Android-Based Smart Home Technology," in *2021 7th International HCI and UX Conference in Indonesia (CHIuXiD)*, pp. 33–38, 2021, doi: 10.1109/CHIuXiD54398.2021.9650605.

[81] W.-T. Sung, I. G. T. Isa, and S.-J. Hsiao, "An IoT-Based Aquaculture Monitoring System Using Firebase," *Comput. Mater. Contin.*, vol. 76, no. 2, pp. 2179–2200, 2023, doi: 10.32604/cmc.2023.041022.