Design and Development of An Intelligent Automatic Tilapia Fish Farming Device in A Bucket Based on Internet of Things

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ABSTRACT
The cultivation of various freshwater fish species, such as catfish, tilapia, carp, and sepat, can be effectively managed through the budikdamber technique, where fish and vegetables are grown together in a single container. This research introduces an alternative method designed to control water temperature, automate fish feeding, and cover the container automatically when it rains. By integrating monitoring and control devices, budikdamber owners can manage automated feeding, monitor water temperature, measure pH levels, control water depth, and automatically activate rain covers. This smart device is expected to enhance budikdamber management efficiency, contributing to the improved welfare of the fish and overall system sustainability.

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1. INTRODUCTION

With rapid infrastructure development limiting land for fish farming and gardening, and growing demand for protein, Budikdamber (Fish Farming in Buckets) offers a practical solution for small-scale, efficient fish and vegetable cultivation on limited land. This method is affordable and accessible for households, helping meet local nutritional needs. This study explores Budikdamber's potential to optimize water use and simplify farming, providing a sustainable, low-cost approach to self-sufficiency in nutrition [1].

The Budikdamber method allows the cultivation of various freshwater fish species, such as catfish, tilapia, and gourami, using a polyculture approach to raise fish and vegetables together in the same container. This research addresses the challenges of limited land and high resource use in traditional farming. By evaluating Budikdamber, the study aims to assess its potential as a sustainable, low-cost solution for small-scale, integrated fish and vegetable farming, promoting efficient use of space and water while meeting local nutritional needs [2]. Compared to the more complex aquaponics system, which requires pumps, filters, large spaces, and high investment costs, *Budikdamber* offers a simpler and more accessible approach. This method provides several advantages, including efficient water use, minimal waste production, straightforward maintenance, and the elimination of harmful chemicals.

This research evaluates the Budikdamber technique as a sustainable, cost-effective solution for small-scale aquaculture and agriculture. It highlights how Budikdamber enables resource-limited communities to engage in self-sufficient food production while conserving space and resources. While traditional methods are more suited to rural areas, urban families may find tilapia farming challenging due to the fish's sensitivity to water conditions. This study proposes IoT integration to automate feeding, water quality monitoring, and rain protection, making Budikdamber more feasible for urban settings by ensuring optimal conditions with minimal manual effort [3], [4]. Tilapia farming in buckets can be difficult for users with busy schedules who can't regularly monitor their system. To address this, the traditional Budikdamber method is enhanced with IoT for remote monitoring and control, reducing the need for constant physical presence. This study integrates IoT to automate key functions like water temperature and pH monitoring, feeding, and rain protection, making Budikdamber more accessible to urban residents. IoT-enabled automation ensures optimal tilapia farming conditions, offering a sustainable, efficient solution for urban agriculture.

Technological advancements, especially in control and automation, are making direct interactions with systems a part of daily life. The Internet of Things (IoT) facilitates seamless device communication, real-time monitoring, and automation with minimal human involvement. In aquaculture, IoT enhances efficiency by enabling precise control of factors like water quality, temperature, and pH, crucial for fish health. Studies show IoT reduces labor, minimizes errors, and supports sustainable practices. Integrating IoT into Budikdamber systems addresses space and time limitations, making small-scale aquaculture more reliable and accessible for both urban and rural communities [5]. The IoT connects devices to exchange data over the internet without direct human interaction. It offers benefits like real-time monitoring, increased efficiency, and automation. In agriculture and aquaculture, IoT enables precise control of factors such as temperature, humidity, and pH, ensuring optimal conditions with minimal manual effort. Research shows IoT improves resource efficiency, sustainability, and reduces labor, making it ideal for small-scale, resource-constrained systems like Budikdamber. IoT enhances control and reliability, leading to better results and sustainability in both urban and rural settings [6].

In the first study titled Design and Development of an Automatic Feeding System for Fish Farming in Buckets Based on Arduino Mega 318 conducted by Faris, the system in this study features an automatic feeding mechanism [7]. The second study, titled Water Quality Monitoring and Control System as Well as Feeding in Catfish Farming Using Fuzzy Method, NodeMCU, and Telegram, conducted by Rizky Maulana, features a system that monitors and controls water quality and feeding in catfish farming using the fuzzy method, NodeMCU, and Telegram [8]. The third study, titled Water Turbidity Monitoring and Control System for Fish Farming in Buckets (Budikdamber) Based on Internet of Things, conducted by Septian, features a system that monitors water level and turbidity, as well as controls the water level. The application used in this study is Bylink [9]. In the fourth study titled Prototype of a Temperature, Water Level Monitoring, and Automatic Control System for Fish Farming in Buckets Based on IoT, conducted by Abdul Yazid, the system in this study monitors temperature, water level, and provides automatic control using an application [10]. In this study, the Budikdamber system using IoT was developed with the addition of an automatic rain cover feature, which was not present in previous studies. Furthermore, the monitoring system for tilapia farming will send data to be monitored via the web, and notifications will be sent to the Budikdamber owner's email.

This smart device design enables Budikdamber owners to manage fish more efficiently, improving their well-being. It saves time and energy while enhancing maintenance for owners and fish farmers. Unlike previous studies, this system includes a rain-cover that activates automatically during rainfall, a feature not found in earlier designs. Additionally, the IoT monitoring system sends real-time data and notifications via a web interface and email, providing users with updates on water quality and fish health. These innovations offer a unique, accessible solution for remote fish farming in limited spaces.

2. RESEARCH METHOD

The device design in this study will be divided into two parts: hardware design and software design. The hardware design begins with the design of the overall system block diagram. The block diagram plays a crucial role in the research process. The Research Method can view figure 1.

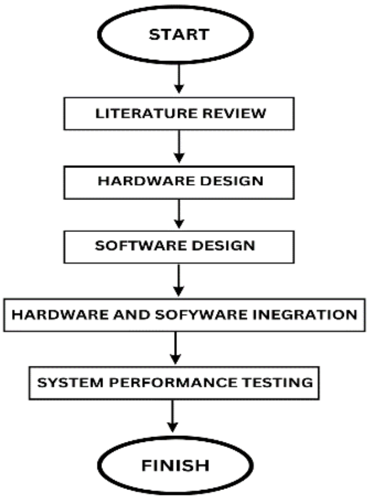

Figure 1. Research Method

Here is the explanation of the research framework diagram at figure 1: (1) Literature Review, this stage involves the researcher gathering data from various sources, including books, theses, journals, and the internet, as reference material for this writing. (2) Hardware Design, in this stage, a block diagram is created to outline the components supporting device development. (3) Software Design:, this step is illustrated in a flowchart that shows the application's operational process. (4) Hardware and Software Integration, this stage combines automatic feeding, water control, water turbidity, pH level, and automatic rain cover with a web server monitoring system. (5) System Performance Testing, in this stage, the system's performance is tested in tilapia farming within a bucket. This includes automatic feeding, monitoring water turbidity levels, pH levels in the bucket, and automatic rain cover that closes when rain is detected.

2.1 Hardware Design

The hardware design involves creating the device, with careful attention to the components used to avoid damage during system testing.

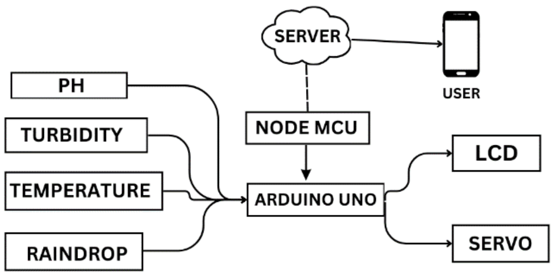

Figure 2. Hardware Design

The explanation is as figure 2:

1. The Arduino Uno is an open-source electronic platform featuring a microcontroller board based on the ATmega328. It is supported by an integrated development environment (IDE) from the Arduino project, which uses a programming language called Processing. The platform is known for its low power consumption, extensive documentation, large libraries, and high portability [11].
2. NodeMCU is a microcontroller that can be configured to connect to the Internet for IoT (Internet of Things) applications. It is an open-source development board based on the ESP8266 microcontroller, which includes an integrated Wi-Fi transceiver. NodeMCU provides a complete hardware and software environment for IoT projects [12].
3. The water pH sensor is a sensor that detects the acidity level of a liquid through a chemical reaction at the tip of the pH probe, which causes a voltage. This voltage is then measured and converted into pH units [13].
4. A turbidity sensor functions as a sensor that can detect water turbidity by reading the optical properties of water caused by light and comparing the reflected light with the incoming light [14].
5. A rain detector is a sensor designed to detect rainfall. It responds when water molecules make contact with its surface, providing data that can be used to measure the intensity of the rainfall [15].
6. LCD is one of the modules used to display results in the form of characters according to our wishes. The LCD screen uses two sheets of material that can polarize and liquid crystals between the two sheets [16].
7. A servo motor is a device or rotary actuator (motor) designed with a closed-loop feedback control system (servo), allowing it to be configured to determine and ensure the angular position of the motor's output shaft [17].

2.2 Software Design

Software design involves controlling the system and systematically processing data from all the programs used.

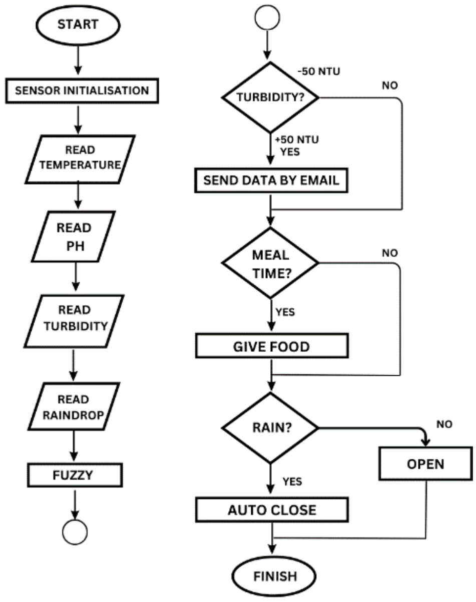

Figure 3. Software Design

The explanation of the software flowchart diagram above is as figure 3:

1. Initialize all sensors present in the smart tool for tilapia farming in a bucket.
2. Read the temperature sensor to continuously monitor the water temperature in the bucket.
3. Read the pH sensor to detect the pH level to determine whether the water quality in the bucket is still good.
4. Read the turbidity sensor to detect the water turbidity in the bucket.
5. Read the rain sensor, which functions as a detector for rainfall and will automatically close the bucket cover when it rains.
6. After reading all the sensors, the process moves to the fuzzy logic system, which checks the water turbidity and pH. If the water in the bucket is turbid, the sensor will send data via email.
7. If the water in the bucket is not turbid and the pH level remains stable, the servo will operate to automatically dispense food according to the portion and schedule.
8. If it rains, the rain sensor will detect it, and the servo will automatically close the tilapia farming bucket. If it does not rain, the tilapia farming bucket will remain open.

2.3 Implementation of Fuzzy Logic Sugeno

2.3.1 Fuzzification

At this stage, the input variables are transferred into fuzzy sets to be used in calculating the truth value of the premises in each rule within the knowledge base. This means that this stage takes crisp values and determines the degree of membership, where these values become members of each corresponding fuzzy set [18]. The Variable Fuzzy can view table 1.

Table 1. Variable Fuzzy

Variable Name	Fuzzy Members	Domain/Parameter
Temperature	Low	0-26
	Medium	24-32
	High	30-40
Turbidity	Not Cloudy	0-52
	Cloudy	48-60
pH	Low	0-6,7
	Medium	6,7-8,7
	High	8,5-9

2.3.2 Inference

This stage involves processing the FuzzyInput generated from fuzzification. The rules formed consist of logical compositions with implication rules and premise sets that produce conclusions. The statements formed are like IF is... THEN is... which have conjunctions with AND. Later, the variables that play a role are FuzzyInput [19]. The Rule Fuzzy can view table 2.

Table 2. Rule Fuzzy

Rule		Temperature		Turbidity		pH		Decision
[R1]	If	Low	And	Not Cloudy	And	Low	Then	Active
[R2]	If	Medium	And	Not Cloudy	And	Low	Then	Off
[R3]	If	High	And	Not Cloudy	And	Low	Then	Active
[R4]	If	Low	And	Cloudy	And	Low	Then	Active
[R5]	If	Medium	And	Cloudy	And	Low	Then	Off
[R6]	If	High	And	Cloudy	And	Low	Then	Active
[R7]	If	Low	And	Not Cloudy	And	Medium	Then	Off
[R8]	If	Medium	And	Not Cloudy	And	Medium	Then	Off
[R9]	If	High	And	Not Cloudy	And	Medium	Then	Active
[R10]	If	Low	And	Cloudy	And	Medium	Then	Off
[R11]	If	Medium	And	Cloudy	And	Medium	Then	Off
[R12]	If	High	And	Cloudy	And	Medium	Then	Active
[R13]	If	Low	And	Not Cloudy	And	High	Then	Off
[R14]	If	Medium	And	Not Cloudy	And	High	Then	Off
[R15]	If	High	And	Not Cloudy	And	High	Then	Active
[R16]	If	Low	And	Cloudy	And	High	Then	Off
[R17]	If	Medium	And	Cloudy	And	High	Then	Active
[R18]	If	High	And	Cloudy	And	High	Then	Active

2.3.3 Defuzzification

The input of the defuzzification process is a fuzzy set obtained from the composition of fuzzy rules, while the output produced is a number within the domain of the fuzzy set. Thus, if a fuzzy set is given within the range [20].

3. RESULTS AND ANALYSIS

The testing results of the device in the design and construction of the smart tilapia fish farming tool in a bucket were conducted to understand the working mechanism of the device in tilapia fish farming in a bucket.

3.1 Test Results of water Conditions in the Bucket

The testing results of the device in the design and construction of the smart tilapia fish farming tool in a bucket were conducted to understand the working mechanism of the device in tilapia fish farming in a bucket.

Table 3. Results of Water Conditions

Sensor pH	Sensor Turbidity	Sensor DHT 11	Water Pump
6.3	4.1	22.5	Active
6.1	4.5	25.3	Off
5.8	3.1	32.5	Active
6.2	52.1	18.2	Active
5.9	51.9	28.4	Off
5.8	51.5	38.5	Active
7.5	3.3	18.7	Active
6.9	5.0	30.3	Off
6.5	4.5	33.8	Active
7.6	52.5	19.5	Off
8.3	51.8	29.6	Off
6.8	51.2	33.6	Active
8.7	4.6	20.5	Off
8.7	52.1	22.9	Off
8.6	5.8	34.2	Active
8.5	4.9	28.9	Off
8.8	52.5	26.5	Active
8.9	51.3	35.3	Active

In Table 3, the test results above show that the fuzzy logic works as specified. With the appropriate fuzzy logic method used, the user will receive notifications about poor water quality, the pump being on, and the pump being off, as shown in the image.

In Figure 4, it is explained that when the water in the bucket becomes turbid, the system will detect it and notify the user via email, as shown in the image. In Figure 5, it is explained that when the water pump is active and the fuzzy logic system reads the data, the system will detect this and notify the user via email that the pump is active, as shown in the image. In Figure 6, it is explained that when the water pump is inactive and the fuzzy logic system reads the data, the system will detect this and notify the user via email that the pump is inactive, as shown in the image.

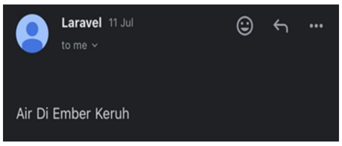

Figure 4. Notification of Turbidity

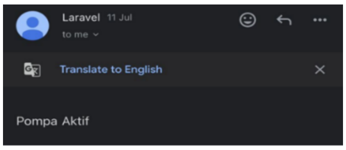

Figure 5. Notification Pompa On

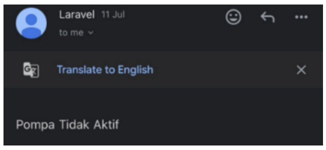

Figure 6. Notification Pompa Off

The following table compares the sensors in the developed device with standard devices available on the market. Table 4 shows the comparison results of the temperature sensor with a room thermometer sold on the market. Table 5 shows the comparison results of the turbidity sensor with water quality instruments sold on the market. Table 6 shows the comparison results of the pH sensor with instruments sold on the market.

Table 4. Comparison Temperature Sensor

No	Temperature Sensor	Original Temperature	Difference	Persentase Error
1.	22.5	22.0	0.5	2.27
2.	25.3	25.0	0.3	1.20
3.	32.5	32.0	0.5	1.56
4.	18.2	18.0	0.2	1.11
5.	28.4	28.0	0.4	1.43
6.	38.5	38.0	0.5	1.32
7.	18.7	18.5	0.2	1.08
8.	30.3	30.0	0.3	1.00
9.	33.8	33.5	0.3	0.90
10.	19.5	19.0	0.5	2.63
11.	29.6	29.0	0.6	2.07
12.	33.6	33.0	0.6	1.82
13.	20.5	20.0	0.5	2.50
14.	22.9	22.5	0.4	1.78
15.	34.2	34.0	0.2	0.59
16.	28.9	28.5	0.4	1.40
17.	26.5	26.0	0.5	1.92
18.	35.3	35.0	0.3	0.86
		Average		1.52

Table 5. Comparison Turbidity Sensor

No	Turbidity Sensor	Original Turbidity	Difference	Persentase Error
1.	4.1	4.0	0.1	2.27
2.	4.5	4.4	0.1	1.20
3.	3.1	3.0	0.1	1.56
4.	52.1	52.0	0.1	1.11
5.	51.9	51.7	0.2	1.43
6.	51.5	51.4	0.1	1.32
7.	3.3	3.2	0.1	1.08
8.	5.0	4.9	0.1	1.00
9.	4.5	4.6	0.1	0.90
10.	52.5	52.3	0.2	2.63
11.	51.8	51.6	0.2	2.07
12.	51.2	51.1	0.1	1.82
13.	4.6	4.5	0.1	2.50
14.	52.1	52.0	0.1	1.78
15.	5.8	5.7	0.1	0.59
16.	4.9	4.8	0.1	1.40
17.	52.5	52.4	0.1	1.92
18.	51.3	51.2	0.1	0.86
		Average		1.37

Table 6. Comparison pH Sensor

No	pH Sensor	Original pH	Difference	Persentase Error
1.	6.3	6.5	-0.2	-3.08
2.	6.1	6.2	-0.1	-1.61
3.	5.8	6.0	-0.2	-3.33
4.	6.2	6.3	-0.1	-1.59
5.	5.9	6.0	--0.2	-1.67

No	pH Sensor	Original pH	Difference	Persentase Error
6.	5.8	5.9	-0.1	-1.69
7.	7.5	7.4	0.1	1.35
8.	6.9	7.0	-0.1	-1.43
9.	6.5	6.6	-0.1	-1.52
10.	7.6	7.5	0.1	1.33
11.	8.3	8.2	0.1	1.22
12.	6.8	6.7	0.1	1.49
13.	8.7	8.6	0.1	1.16
14.	8.7	8.8	-0.1	-1.14
15.	8.6	8.7	-0.1	-1.15
16.	8.5	8.6	-0.1	-1.16
17.	8.8	8.9	-0.1	-1.12
18.	8.9	9.0	-0.1	-1.11
		Average		-0.011

3.2 Result of Automatic Feeding Testing

The testing results for the automatic feeding system in tilapia fish farming in a bucket worked well. The feeder device operates by rotating automatically at scheduled times: in the morning at 08:00, noon at 12:00, and in the afternoon at 16:00, rotating for 5 seconds each time to distribute feed at the designated times. During these scheduled feeding times, users will receive notifications via email regarding the feeding schedule for the fish, as shown in the figure 7.

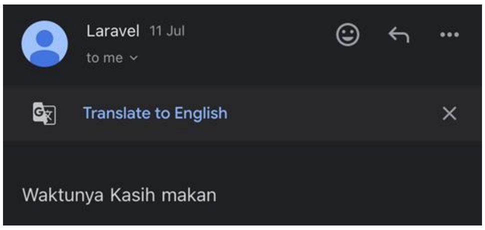

Figure 7. Notification of Feeding Times

3.3 Result of Automatic Rain Cover Testing

The testing of the automatic rain cover on the smart device for tilapia fish farming in a bucket was successful. The rain sensor can detect rain with an output of 1 for rain and 0 for no rain. When it rains, the sensor detects it and the servo immediately closes the cover automatically. If there is no rain, the automatic rain cover device will open the cover to 155 degrees. When it rains, the rain cover will close to 60 degrees, as seen in the figure 8.

Figure 8. Rain Cover Open and Close

3.4 Implementation of Internet of Things

The implementation of IoT in this research is done by applying HTTP requests, which are useful for sending data to the website so that it can be monitored on the website both in real-time and stored in the website's database.

Coding For Http Request

```
  client.setInsecure();  // Bypass SSL certificate verification
  // Construct the URL with the sensor data
  String url = String(serverName) + "?data=" + temperature + "|" + humidity + "|" + ph_data
+ "|" + turbidity + "|" + rain;
  Serial.println("Request URL: " + url);  // Debugging line
  http.begin(client, url);
```

```
  int httpResponseCode = http.GET();
  if (httpResponseCode > 0) {
    Serial.print("HTTP Response code: ");
    Serial.println(httpResponseCode);
    String response = http.getString();
    Serial.println("Response: " + response);
  } else {
    Serial.print("HTTP GET failed, error: ");
    Serial.println(http.errorToString(httpResponseCode).c_str());
```

Coding For Sending Email

```
 if (turbidity >= "50") {
    http.begin(client, "https://budikdamber.sisakma.com/api/sendmail");
    int httpResponseCode = http.GET();
    if (httpResponseCode < 0) {
      Serial.println("HTTP GET failed, error: " +
String(http.errorToString(httpResponseCode)));  // Debugging line
    }
    http.end();
  }
  if (status_pompa.equals("aktif")) {
    http.begin(client, "https://budikdamber.sisakma.com/api/pompaaktif");
    Serial.println("kirim pompa aktif");
    int httpResponseCode = http.GET();
    if (httpResponseCode < 0) {
      Serial.println("HTTP GET failed, error: " +
String(http.errorToString(httpResponseCode)));  // Debugging line
    }
    http.end()
```

In Figure 9, the website display shows all incoming data in real-time.

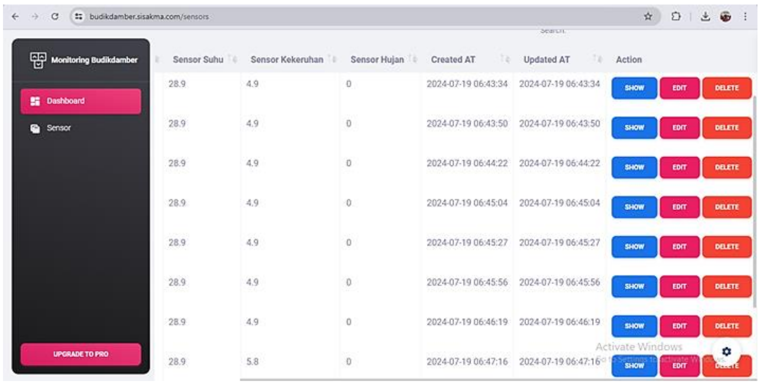

Figure 9. Realtime Display of Website Time

3.5 Analysis

After conducting experiments on the smart tilapia farming tool in a bucket, the results were quite satisfactory. The tests conducted on water quality with the implementation of Sugeno fuzzy logic showed good results. The pH, turbidity, and DHT11 sensors could accurately read the water quality in the tilapia farming bucket, allowing the pump to automatically determine when to activate or deactivate. Users receive notifications about the condition and quality of the water in the bucket. Although the water in the bucket can become dirty quickly, the quality measured by all sensors still meets the needs for tilapia farming, allowing the fish to thrive. For the automatic feeding system, the tool operates according to the desired schedule. The automatic feeder with relay and NodeMCU dispenses food to the tilapia according to the pre-set schedule with a 5-second cycle.

During feeding, users receive notifications via email with information about the feeding status. However, if the NodeMCU loses internet connection, the automatic feeder will not operate according to the schedule, and users will not receive notifications about the feeding schedule. For the automatic rain cover test, the cover opens to 155 degrees or half of the bucket, and closes to 60 degrees in the event of rain. Testing the rain sensor showed successful operation of the automatic cover; the rain sensor, assisted by the servo, closes the cover with an output of 1 if it detects rain, and if no rain is detected, the servo opens the cover to 155 degrees. This study developed the IoT-based Budikdamber system with an automatic rain cover feature that was not present in previous studies. Notifications about water quality, pump status, and feeding times are sent to the Budikdamber owner via email.

4. CONCLUSION

The automatic feeding system for tilapia farming in a bucket operates according to the predetermined schedule, which is at 8:00 AM, 12:00 PM, and 4:00 PM, with a duration of 5 seconds each time, and the user receives email notifications about the feeding schedule. The monitoring and control system for water, pH, and turbidity uses the Sugeno fuzzy logic method to ensure water quality, with the water pump being activated or deactivated based on the water quality in the bucket. The automatic rain cover tool works very satisfactorily, with the rain sensor detecting rain (result 1) and no rain (result 0), and when rain is detected, the servo operates to close the cover automatically. Overall, the performance of the IoT-based smart tool for tilapia farming in a bucket is very satisfactory, with all sensors providing information as expected.

REFERENCES

[1] S. Suryanti, A. Umami, R. Firmansyah, R. Widyasaputra, and F. Pertanian, "Pemberdayaan Pertanian Organik Dengan Model Hidroganik Budikdamber Di Era Pandemi Covid – 19 Di Kabupaten Bantul Provinsi Diy," 2020. [Online]. Available: http://journal.ummat.ac.id/index.php/

[2] N. Purnaningsih *et al.*, "Diseminasi Budidaya Ikan Dalam Ember Sebagai Solusi Kegiatan Budidaya di Lahan Sempit (Dissemination of Aquaculture in The Buckets as Solutions for Cultivation Activities in Narrow Lands)," Edisi Khusus.

[3] Y. Cahyanti and I. Awalina, "Studi Literatur : Pengaruh Suhu terhadap Ikan Nila (Oreochromis niloticus)," *Panthera : Jurnal Ilmiah Pendidikan Sains dan Terapan*, vol. 2, no. 4, pp. 224–235, Oct. 2022, doi: 10.36312/pjipst.v2i4.110.

[4] C. P. Adi and A. Suryana, "Pola Pertumbuhan Ikan Nila Oreochromis Niloticus Di Fase Pendederan," *KNOWLEDGE: Jurnal Inovasi Hasil Penelitian dan Pengembangan*, vol. 3, no. 2, pp. 147–158, Jul. 2023, doi: 10.51878/knowledge.v3i2.2372.

[5] A. Halim, M. Nasution, N. Fadhilah, C. Arifin, and P. Tamba, "Pengontrolan Lampu Jarak Jauh Dengan Nodemcu Menggunakan Blynk," *Jurnal TEKINKOM*, vol. 2, 2019.

[6] S. Fatriana Kadir, "Mobile Iot (Internet Of Things) Untuk Pemantauan Kualitas Air Habitat Ikan Hias Pada Akuarium Menggunakan Metode Logika Fuzzy," 2019.

[7] F. N. Haq and N. S.Kom, "Rancang Bangun Sistem Otomatis Pemberian Pakan Pada Budidaya Ikan Dalam Ember (Budikdamber) Berbasis Arduino Uno Atemega 328," *Jurnal Ilmiah ILKOMINFO - Ilmu Komputer & Informatika*, vol. 6, no. 2, pp. 158–165, Jul. 2023, doi: 10.47324/ilkominfo.v6i2.178.

[8] R. Maulana, K. Kusnadi, and M. Asfi, "Sistem Monitoring dan Controlling Kualitas Air Serta Pemberian Pakan Pada Budidaya Ikan Lele Menggunakan Metode Fuzzy, NodeMCU dan Telegram," *ITEJ (Information Technology Engineering Journals)*, vol. 6, no. 1, pp. 53–64, Oct. 2021, doi: 10.24235/itej.v6i1.57.

[9] A. Septian and R. Syahputri, "Sistem Monitoring Kekeruhan Dan Ketinggian Air Pada Budidaya Ikan Dalam Ember (Budikdamber) Berbasis Internet Of Things".

[10] A. Yazid, Weny Indah Kusumawati, and R. Febriliana, "Prototipe Sistem Monitoring Suhu, Ketinggian Air, dan Kontrol Otomatis pada Budikdamber Berbasis IoT," *Journal of Advances in Information and Industrial Technology*, vol. 5, no. 2, pp. 93–104, Nov. 2023, doi: 10.52435/jaiit.v5i2.371.

[11] Saleh Elkelani Babaa, Muneer Ahmed, S. A. K. Babatunde Samuel Ogunleye, and J. R. P. Salim Ahmed Al-Jahdhami, "Smart Irrigation System using Arduino with Solar Power," *International Journal of Engineering Research and*, vol. V9, no. 05, May 2020, doi: 10.17577/IJERTV9IS050088.

[12] K. T. Wai, N. P. Aung, and L. L. Htay, "Internet of Things (IoT) Based Healthcare Monitoring System using NodeMCU and Arduino UNO," *International Journal of Trend in Scientific Research and Development (IJTSRD) International Journal of Trend in Scientific Research and Development*, no. 5, pp. 755–759, 2019, doi: 10.31142/ijtsrd26482.

[13] M. T. Ghoneim *et al.*, "Recent Progress in Electrochemical pH-Sensing Materials and Configurations for Biomedical Applications," *Chem Rev*, vol. 119, no. 8, pp. 5248–5297, Apr. 2019, doi: 10.1021/acs.chemrev.8b00655.

[14] K. Adriansyah, E. Permata, and B. D. Cahyono, "Prototype Penetas Telur Ayam Kampung Menggunakan Arduino Nano V3.0 ATmega328," *AVITEC*, vol. 5, no. 2, p. 97, Aug. 2023, doi: 10.28989/avitec.v5i2.1672.

[15] M. Faisal, Z. Mutiara, S. Awwal Miftah Hidayat, A. Rinaldi Basrida, and M. T. Fazrin, "Prototype of Water Level and Rainfall Detection System as Flood Warning Based On Blynk Iot Application," *International Transactions on Education Technology (ITEE)*, vol. 2, no. 1, pp. 1–10, Aug. 2023, doi: 10.33050/itee.v2i1.361.

[16] S. Mluyati and S. Sadi, "Internet Of Things (Iot) Pada Prototipe Pendeteksi Kebocoran Gas Berbasis MQ-2 dan SIM800L," *Jurnal Teknik*, vol. 7, no. 2, Feb. 2019, doi: 10.31000/jt.v7i2.1358.

[17] S. Autsou, K. Kudelina, T. Vaimann, A. Rassõlkin, and A. Kallaste, "Principles and Methods of Servomotor Control: Comparative Analysis and Applications," *Applied Sciences*, vol. 14, no. 6, p. 2579, Mar. 2024, doi: 10.3390/app14062579.

[18] S. Nurdini, G. W. Nurcahyo, and J. Santony, "Analisis Perkiraan Jumlah Produksi Tahu Menggunakan Metode Fuzzy Sugeno," *Jurnal Sistim Informasi dan Teknologi*, pp. 18–23, Sep. 2019, doi: 10.37034/jsisfotek.v1i3.4.

[19] M. Deta Gian Faiz, Andrian Rakhmatsyah, and R. Yasirandi, “Klasifikasi Data Aktivitas Setelah Joging Menggunakan Fuzzy Logic,” *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)*, vol. 5, no. 3, pp. 534–542, Jun. 2021, doi: 10.29207/resti.v5i3.2938.
[20] M. Irfan, C. N. Alam, and D. Tresna, “Implementation of Fuzzy Mamdani Logic Method for Student Drop Out Status Analytics,” *J Phys Conf Ser*, vol. 1363, no. 1, p. 012056, Nov. 2019, doi: 10.1088/1742-6596/1363/1/012056.

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