Prediction Of Freshwater Fish Pond Water Quality Levels Using The Backpropagation Method Based On The Internet Of Things (IoT)

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Abstract.
The present study reports the first comprehensive study on the freshwater macroinvertebrates and its habitat preferences in Bilah River, the largest riverin the Northern Sumatra. The riverside is characterized by the presence of anthropogenic and industrial activities which may alter the macroinvertebrate assemblage and biodiversity. Five months of investigation on 10 sampling stations from December 2016 to October 2017 was conducted based on the river flow in Bilah River. Principal component analysis indicated a decrease in trophic status from upstream to downstream of the river. A total of 27 taxa were recorded, with the most abundant group were members of Odonata, Gastropoda, and Decapoda. The highest density of macroinvertebrate was observed from station 1 (160 ind m-2), while the lowest density was observed from station 9 (38.64 ind m^{-2}). Based on species distribution and similarity, two groups of habitats may be distinctively recognized based on the Bray-curtis similarity coefficient. Group 1 consisted of station 1, 2, 3 and 4 while group 2 consisted of station 5, 6, 7, 8, 9, and 10. Based on the diversity indices as ecological parameters, the habitat condition in Bilah River is categorized from low to moderately polluted. Spatial patterns in both environmental conditions affecting the macroinvertebrate assemblage was observed using canonical correspondence analysis (CCA) revealed the preferences from each macroinvertebrate species towards environmental conditions.

Keywords: *Bivalvia, bray-curtis, cannonical correspondence analysis, density, gastropoda.*

I. INTRODUCTION

Prediction or forecasting is a method of estimating something that will happen in the future based on current and past data (Petropoulos et al., 2022). One type of data used in prediction is time series data, which is usually found in biological, air quality, weather, astronomical, and financial measurements (Mueller & Massaron, 2021). In the context of air quality measurement, time series data helps represent various parameters, such as temperature, air acidity, oxygen levels, turbidity, and other chemical content.In fish farming, water quality is a crucial factor that determines the survival of aquatic biota, because the entire life cycle of fish takes place in water (Cloete et al., 2016). In addition to being clean and free from pollution, water used for fish farming must also pay attention to certain physical and chemical parameters (Engel et al., 2012). Several physical and chemical properties of water that are important to consider in freshwater fish farming include temperature, water exchange, depth, turbidity, dissolved oxygen levels, pH, and heavy metal concentrations, especially Mercury (Hg) (Azhra & Anam, 2021). These parameters greatly affect the fish's living environment, and deviations from the established standards can have a negative impact on the success of farming (Eneh et al., 2023). Water quality standards for freshwater fish farming can be further seen in Table 1, which outlines the ideal ranges for various important parameters in maintaining optimal water quality for fish survival.

Table 1. Water Quality Parameters in Freshwater Fish Cultivation

Parameter Types	Unit	Range
Temperature	^{o}C	25-32
pH	-	6.5-8.5
Dissolved oxygen	mg/I	≥ 3
Ammonia	mg/I	< 0.02
Brightness	Cm	30-40
Cadmium	Ppm	0.01
Lead	Ppm	0.03
Hg	Ppm	0.001

NH3	Mg/Lt	< 0.016
Turbidity	Cm	40-50
CO2	Mg/Lt	< 15
Nitrite (NO2)	Ppm	< 0.05
Alkalinity	Mg/Lt	> 20
Total Hardness	Mg/Lt	> 20

Regular water quality monitoring is needed to determine whether water quality parameters have exceeded the limits set in Government Regulation of the Republic of Indonesia No. 82 of 2001 concerning water quality management and pollution control. Water quality is very important in freshwater fish farming because it plays a role in determining success (Islam et al., 2023). Poor water quality can affect fish health; even if the pond water looks clean, the fish may not grow optimally and are at risk of crop failure (Arafat et al., 2020). Several factors that affect water quality include pH, temperature, oxygen levels, and water turbidity levels [9]. Therefore, a water quality monitoring system is needed to ensure water suitability (Hemal et al., 2024). Therefore, a water quality monitoring system is very necessary to ensure the suitability of water (Hemal et al., 2024). One way to find out the condition of water quality in a pond is to use a tool that can detect water quality before the fish die (Putra et al., 2024). With this detection system, freshwater fish farmers will immediately know if the water quality in their ponds is decreasing (Candra et al., 2023). The detection system can be done automatically, which provides information about certain conditions that can be applied, such as in freshwater fish ponds that require attention(Chen et al., 2022).

The development of a freshwater fish pond water quality monitoring system using an artificial neural network with the backpropagation method based on the Internet of Things (IoT) needs to be done to prevent crop failure due to non-compliance of water quality with quality standards (Candra et al., 2024). In this study, the system was designed not only to be able to monitor and classify water quality based on pH parameters, oxygen levels, turbidity index, and temperature, but also to automatically predict water quality conditions using an artificial neural network (ANN) algorithm. Data is obtained from sensors integrated with an Arduino microcontroller, which is processed using the backpropagation method, and the results will be delivered via an IoT-based mobile device. In addition, this system is also equipped with a warning indicator in the form of a buzzer that can provide a quick response to changes in water quality. Another advantage of this study is the use of alternative power in the form of solar cell-based batteries to keep the monitoring system operating 24 hours without depending on PLN electricity, which often goes out or is expensive. This study combines IoT technology, artificial neural networks, and renewable energy to increase the effectiveness and efficiency of water quality management in the freshwater fish farming sector.

II. METHODS

This study uses a field experiment method with the aim of designing a freshwater fish pond water quality detection system based on artificial neural networks (ANN) and the Internet of Things (IoT). The research process includes several stages, as follows:

1. Monitoring System Design

This stage includes the design of the hardware for the water quality monitoring system. The hardware used includes MQ-2, MQ-6, DHT-22 sensors, and pH sensors, as well as additional components such as buzzers, relays, NodeMCU ESP32S, I2C LCDs, and pumps (Rochman et al., 2017). This device will function as the main tool in detecting water quality parameters such as gas, temperature, humidity, and pH of water.

2. Sensor Testing

The testing was conducted by placing each sensor in a fish pond at a certain distance to measure water quality parameters. The output results from the sensors, such as voltage in ppm, will be analyzed to determine the optimal detection range for each sensor.

3. Sensor Calibration

The sensor measurements are compared with standard measuring instruments to validate the accuracy of the sensor being used. This stage ensures that the detection results from the sensor are close to the results of recognized standard measurements, so they can be used in the monitoring system.

4. Artificial Neural Network Programming

Artificial neural networks are created using the Python programming language. This JST is trained with a dataset from pond monitoring that includes physical parameters such as water pH, temperature, oxygen levels, and water concentration (Jiang & Yan, 2022). After the training, the JST is used to predict and classify water quality based on the sensor data received.

5. IoT System Design

At this stage, the monitoring results are integrated with an IoT system that allows for water quality monitoring via the internet. The IoT system is designed using the Blynk platform, where the detection results from the sensors can be accessed in real-time through a website and mobile application.

6. Data retrieval

The data obtained from the detection of physical parameters (pH, temperature, oxygen, turbidity) will be recorded and analyzed. The output from the monitoring system will be displayed both through the LCD and the IoT interface that has been created. This data is used as a basis for the evaluation and analysis of water quality and the effectiveness of the designed monitoring system.

7. Results Analysis

The data collected from various tests and observations will be statistically analyzed and discussed to determine the extent to which this system can effectively detect changes in water quality. The results of the analysis will also be used to improve the accuracy of JST predictions and ensure the practicality of the IoT-based monitoring system in real-world contexts. Through these stages, the IoT and JST-based fish pond water quality monitoring system is expected to help prevent harvest failures and facilitate efficient and real-time monitoring. This research involves the design of a device that is divided into two parts: hardware design and software design. The design phase begins with creating a system block diagram as a whole to illustrate the data flow from the sensor to the monitoring application. Here are the design steps that were taken

8. Hardware Design

System Block Diagram

The system begins with the creation of a block diagram that illustrates the data flow from various sensors to the microcontroller and server.

Sensor

The main hardware in this system consists of a pH sensor, a Dissolved Oxygen (DO) sensor, a turbidity sensor, and a temperature sensor installed in the freshwater fish pond. This sensor is used to detect water quality parameters such as acidity, dissolved oxygen levels, turbidity, and temperature.

Arduino UNO

Arduino UNO acts as a microcontroller that collects data from these sensors. Each sensor is connected to an Arduino which then converts the physical data from the sensor into a digital signal that can be processed.

Raspberry Pi

The data collected by the Arduino will be forwarded to the Raspberry Pi, which functions as the main server. The Raspberry Pi will process the data received from the Arduino and store it for monitoring purposes.

Additional Components

In addition to sensors and microcontrollers, the system is also equipped with a communication module (e.g., Wi-Fi or Ethernet) that allows the Raspberry Pi to connect to an internet network, as well as a display to display information locally.

9. Software Design

Arduino Programming

The software on the Arduino UNO is responsible for controlling the sensors and sending the data from the readings to the Raspberry Pi. The Arduino programming code is written to periodically read data from the pH, DO, turbidity, and temperature sensors, and to transmit the results to the Raspberry Pi via a serial communication protocol.

Raspberry Pi Server Programming

The Raspberry Pi functions as a server that processes and stores data from the Arduino. Programming on the Raspberry Pi is done using Python or Node.js. The Raspberry Pi will set up a database to store incoming data and display water quality information in real-time.

Monitoring Application

The data processed by the Raspberry Pi will be displayed in a monitoring application. This application is designed to be accessed both locally (via LAN) and publicly. (melalui internet). This application allows users to view water quality data such as pH, DO, turbidity, and temperature from anywhere and at any time.

User Notifications

The system is also equipped with a notification feature that sends alerts to users if water quality parameters exceed the predetermined thresholds.

III. RESULT AND DISCUSSION

1. System Analysis

In this research, the designed system is a control system that can automatically turn on and off the freshwater fish aquarium filter pump according to a predetermined schedule using pH and temperature sensors, and the data is trained using artificial neural networks to detect water quality in fish farming ponds by placing the device at the edge of the pond. Freshwater is obtained from pH and temperature sensors. The sensor will take freshwater when the time set by the RTC has been reached, with the RTC set from 8 AM to 2 PM. After the operating hours have ended, the system will be on standby. To estimate the quality of freshwater, the method used is the Artificial Neural Network (ANN) method. Once the estimated freshwater quality is achieved, the next process involves using the output of the quality estimation as information about the water condition, both on-site using a 16x2 LCD based on I2C in text form and in a mobile format.

2. System Design

System design requires software to manage various hardware components so that they can work together to complete the given tasks. The design of software to carry out the processing of freshwater generated by sensors until the estimated time that can be determined by artificial neural networks. The entire program code will be executed on the Arduino UNO using the Arduino IDE as the software to program the microcontroller so that the components can operate according to the program that has been integrated with the Arduino UNO. The hardware setup consists of a combination of sensors and Arduino, as shown in figure 1.

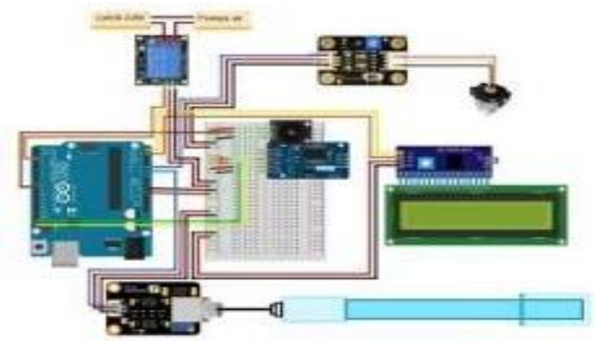

Fig 1. Hardware Design Schematic

3. Network Model Design

Before carrying out the estimation process, a network model is first prepared.

Network Input and Output

In artificial neural networks, there is a need for training data and testing data from processed variables, namely data from pH sensors and temperature sensors in 30 different types of pond water with optimal water quality. In this study, the network model uses four inputs: pH (X1), temperature (X2), dissolved oxygen (X3), and turbidity (X4), with the output being the estimated freshwater level (Y) as the target for the water quality support equipment.

Number of Layers

The backpropagation network is generally constructed with three layers: the input layer, the hidden layer, and the output layer. In this study, a hidden layer is used because, generally, a network with a single hidden layer is sufficient to map between the input and the target with the specified level of accuracy.

Number of Neurons

The number of neurons in the input layer is determined by the number of inputs used in the network. If the model used has two inputs and one output. In the hidden layer, there are no provisions regarding the determination of the number of neurons.

Data

The data is divided into training data and testing data. The training data is taken from 2/3, and the testing data is taken from 1/3 of the total data. Before processing, the data will be normalized first so that the results of the sigmoid function calculations do not fall into the saturation region.

Network Parameters

The parameters that need to be set are the maximum epoch and learning with Maximum epoch = 12000 and Learning Rate = 0.01. In conducting the learning, the researcher has conducted trial and error, the researcher has tried from 2000 to 12000 iterations, the ideal iteration required is 12000. If it is more than that, it will cause the algorithm to become unstable. In this study, a learning rate of 0.01 was used.

Training Process

Initial weight initialization of network training process on pH, Temperature, DO and Turbidity.

Testing Process

The testing process was carried out on a laptop using neurona. Testing of test data using the final weights obtained in the training process. The test results are shown in Table 2. Where the average error in the form of MAPE produced is 12.6% which is included in the "Good" category.

Table 2. Forecasting Accuracy Based on MAPE

No	MAPE fresh water	Forecast Accuracy
1	MAPE ≤ 10%	Accurate
2	10% <MAPE≤20%	Good
3	20% <MAPE≤50%	Fair
4	MAPE>50%	Low

Sumber: (Maricar, 2019)

Results that give an error of less than 10% that are included in the "accurate" category will also be analyzed because this can happen. Possible causes of errors, such as (1) unfavorable weather, rain, or cloudy weather, can cause errors in the system. Every day the weather will change, which causes sunlight to not be able to shine on the aquarium. (2) Errors that occur due to poor time estimation results. Poor time estimation results can affect the entire process because it is the initial process in determining time estimation. (3) Training data that is not diverse enough can cause errors due to errors in determining the estimation.

4. Development of Pond Water Monitoring System

For the sustainability of the program, it is planned to produce a design for a water quality monitoring system in freshwater fish ponds. This system consists of various interconnected tools to determine the quality of the water, such as Arduino components, water quality sensors, and mobile equipment. All of these components are assembled into a water quality monitoring tool using the Artificial Neural Network method based on IoT.

Fig 2. Water Monitoring Device

Control testing before the sensor is used shows that the fresh water that comes out of the monitoring application on the smartphone will show results like the following figure 21:

Fig 3. Mobile application before use

This research produces a design of a water quality monitoring system in a freshwater fish pond, a self-initiating system of various interconnected devices to determine the quality of the water, such as Arduino components, temperature sensors, and pH sensors. All of these components are assembled into a water quality monitoring tool. The use of a microcontroller in order to unite the detection sensors at the testing stage; the sensors consist of temperature sensors, pH and humidity sensors, and dissolved oxygen sensors.

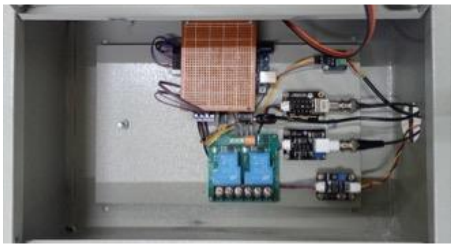

Fig 4. Automatic Sensor Device

In the process of automation and sensor data retrieval, coding is carried out on the microcontroller device using the Arduino IDE software. In the coding, 4 sensors are used on each microcontroller, namely the water temperature sensor, turbidity sensor, TDS sensor, and oxygen sensor in water (DO). The four sensors are coded to be displayed on the LCD layer to show the water condition indicator.

5. Temperature Sensor Testing

This test is done by opening the monitoring application on an Android smartphone to find out whether the temperature sensor is working properly or not, because the sensor is useful for knowing the water temperature in the freshwater fish pond being monitored. If the temperature of the freshwater fish pond rises above 38°C, the monitoring application on the smartphone will provide a notification: "Watch out, the water is starting to get hot.".

Table 3. Temperature Sensor Testing

No	Time	Point	Temperature Sensor	Thermometer	Difference
1	12.00 WIB	1	28.12°C	28°C	0.12 °C
		2	28.56°C	29°C	0.44 °C
		3	28.31°C	29°C	0.69 °C
		4	28.12°C	29°C	0.88 °C
		5	28.37°C	28°C	0.37 °C
2	13.00 WIB	1	27.43°C	29°C	1.57 °C
		2	28.44°C	29°C	0.56 °C
		3	28.37°C	29°C	0.63 °C
		4	28.25°C	29°C	0.75 °C
		5	28.12°C	28°C	0.12 °C
3	14.00 WIB	1	28.12°C	28°C	0.12 °C
		2	28.56°C	29°C	0.44 °C
		3	28.31°C	29°C	0.69 °C
		4	28.12°C	29°C	0.88 °C
		5	28.37°C	28°C	0.37 °C

Based on the results of table 3 levels of testing of water temperature from field data, the test obtained a total difference of 0.575, as seen in the calculation (0.12 + 0.44 + 0.69 + 0.88 + 0.37 + 1.57 + 0.56 + 0.63 + 0.75 + 0.12 + 0.12 + 0.44 + 0.69 + 0.88 + 0.37) / 15 = 8.63 / 15 = 0.575. The comparison between the temperature sensor and the thermometer provides a difference in calculations that produce good-accuracy fresh water or can be said to be almost similar to a real thermometer.

6. pH Sensor Testing

This test is done by opening a monitoring application on an Android smartphone to find out whether the pH sensor is working properly or not, because the sensor is useful for determining the pH level of the water in the freshwater fish pond being monitored. If the acidity level of the freshwater fish pond is less than 5, the Blynk application on the smartphone will provide a notification "the water pH is too acidic," and if the acidity increases more than that, then the smartphone will provide a notification "the water pH is too alkaline".

Table 4. PH Sensor Testing

No	Time	Point	pH Sensor	pH Meter	Difference
1	12.00 WIB	1	7.243pH	8.4pH	1.157
		2	7.062pH	8.2pH	1.138
		3	7.007pH	8.2pH	1.193
		4	7.109pH	8.1pH	0.991
		5	7.007pH	8.0pH	0.993
2	13.00 WIB	1	7.090pH	8.1pH	1.01
		2	7.330pH	7.9pH	0.57
		3	6.952pH	7.9pH	0.948
		4	6.984pH	7.8pH	0.816
		5	7.030pH	7.8pH	0.77
3	14.00 WIB	1	7.062pH	7.8pH	0.738
		2	7.128pH	7.8pH	0.672
		3	6.951pH	7.8pH	0.849
		4	6.987pH	7.8pH	0.831
		5	6.959pH	7.7pH	0.741

Based on the results of table 5 levels of testing of water pH from field data, the comparison between the pH meter as a measuring tool with the pH sensor has a less than satisfactory measurement difference from the test results. Because the fresh water obtained is less suitable for using a pH meter. This deficiency is very influential because the acidity level is only 1-14, if there is a difference exceeding 1 it will be very influential.

IV. CONCLUSION

The results of this study can be concluded that (1) utilizing JST to process data from pH and temperature sensors on 30 different types of pond water with optimal water quality. The network model uses two inputs, namely pH (X1) and temperature (X2), with the output being an estimated time (Y) in minutes to turn on the aquarium water pump. The artificial neural network was trained with 2/3 of the data for training and 1/3 of the data for testing. The network settings include 12 neurons in the hidden layer, a maximum of 12,000 iterations, and a learning rate of 0.01. (2) JST successfully provided an accurate time estimate to operate the water pump based on readings from the pH and temperature sensors, through training and testing. (3) The tests carried out showed an accuracy level of 87.4% with a mean absolute percentage error (MAPE) of 12.6%, which is included in the "good" category.

(4) The 4502C pH sensor and temperature sensor were proven to be able to measure water quality accurately. The pH sensor has an accuracy of 95.26% with an average error of 4.74%, while the temperature sensor has an accuracy of 97.69% with an average error of 2.31%. (5) This system has an average execution speed of 3.29 seconds in processing data from the sensor to determining when the pump is on. This speed is significantly faster than the manual method, which can increase fish farming productivity if the system is applied directly. The system's operating hours are from 8 a.m. to 3 p.m., where the system will automatically

activate and deactivate the pump and other devices according to schedule. Overall, the designed system is effective in monitoring and controlling water quality automatically with a fast response time and high accuracy, making a positive contribution to fish farming productivity.

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REFERENCES

[1] Arafat, A. I., Akter, T., Ahammed, Md. F., Ali, Md. Y., & Nahid, A.-A. (2020). A dataset for internet of things based fish farm monitoring and notification system. *Data in Brief*, *33*, 106457. https://doi.org/10.1016/j.dib.2020.106457

[2] Azhra, F. H., & Anam, C. (2021). IoT-based Automatic Fish Pond Control System. ***IPTEK Journal of Proceedings Series***, *6*,. https://doi.org/10.12962/j23546026.y2020i6.11128

[3] Candra, H. K., Cahyani, R. F., Bahit, M., Noor, S., & Mulyani, D. (2023). Pembuatan Kolam tarpaulin Fish Budidaya Ikan Air Tawar Sistem Resirkulasi Warga Aliran Sungai Kemuning Banjarbaru Kalimantan Selatan. ***Wahana Dedikasi: Jurnal PkM Ilmu Kependidikan***, *6*(2), Article 2. https://doi.org/10.31851/dedikasi.v6i2.13044

[4] Candra, H. K., Noor, S., Bahit, M., Cahyani, R. F., Nugrahadi, D. T., & Mulyani, D. (2024). Analysis and design of pool water quality monitoring system bioflok engineering using Artificial Neural Network based on internet of things. *AIP Conference Proceedings*, *2952*(1), 090010. https://doi.org/10.1063/5.0212273

[5] Chen, C.-H., Wu, Y.-C., Zhang, J.-X., & Chen, Y.-H. (2022). IoT-Based Fish Farm Water Quality Monitoring System. *Sensors*, *22*(17),. https://doi.org/10.3390/s22176700

[6] Cloete, N., Malekian, R., & Nair, L. (2016). Design of Smart Sensors for Real-Time Water Quality Monitoring. *IEEE Access*, *4*, 1–1. https://doi.org/10.1109/ACCESS.2016.2592958

[7] Eneh, A. H., Udanor, C. N., Ossai, N. I., Aneke, S. O., Ugwoke, P. O., Obayi, A. A., Ugwuishiwu, C. H., & Okereke, G. E. (2023). Towards an improved internet of things sensors data quality for a smart aquaponics system yield prediction. *MethodsX*, *11*. https://doi.org/10.1016/j.mex.2023.102436

[8] Engel, D. W., Dalton, A. C., Anderson, K. K., Sivaramakrishnan, C., & Lansing, C. (2012). *Development of Technology Readiness Level (TRL) Metrics and Risk Measures* (PNNL-21737). Pacific Northwest National Lab. (PNNL), Richland, WA (United States). https://doi.org/10.2172/1067968

[9] Hemal, M. M., Rahman, A., Nurjahan, Islam, F., Ahmed, S., Kaiser, M. S., & Ahmed, M. R. (2024). An Integrated Smart Pond Water Quality Monitoring and Fish Farming Recommendation Aquabot System. *Sensors*, *24*(11),. https://doi.org/10.3390/s24113682

[10] Islam, M., Kashem, M., Alyami, S., & Moni, M. (2023). Monitoring water quality metrics of ponds with IoT sensors and machine learning to predict fish species survival. *Microprocessors and Microsystems*, *102*, 104930. https://doi.org/10.1016/j.micpro.2023.104930

[11] Jiang, Y., & Yan, F. (2022). Aquaculture Prediction Model Based on Improved Water Quality Parameter Data Prediction Algorithm under the Background of Big Data. ***Journal of Applied Mathematics***, *2022*(1), 2071360.

[12] Maricar, M. A. (2019). Analisa Perbandingan Nilai Akurasi Moving Average dan Exponential Smoothing untuk Sistem Peramalan Pendapatan pada Perusahaan XYZ. ***Jurnal Sistem Dan Informatika (JSI),*** *13*(2).

[13] Mueller, J. P., & Massaron, L. (2021). *Artificial Intelligence For Dummies*. John Wiley & Sons.

[14] Petropoulos, F., Apiletti, D., Assimakopoulos, V., Babai, M. Z., Barrow, D. K., Ben Taieb, S., Bergmeir, C., Bessa, R. J., Bijak, J., Boylan, J. E., Browell, J., Carnevale, C., Castle, J. L., Cirillo, P., Clements, M. P., Cordeiro, C., Cyrino Oliveira, F. L., De Baets, S., Dokumentov, A., … Ziel, F. (2022). Forecasting: Theory and practice. ***International Journal of Forecasting***, *38*(3), 705–871. https://doi.org/10.1016/j.ijforecast.2021.11.001

[15] Putra, F. P. E., Ubaidi, U., Saputra, R. N., Haris, F. M., & Barokah, S. N. R. (2024). Application of Internet of Things Technology in Monitoring Water Quality in Fishponds. *Brilliance: Research of Artificial Intelligence*, *4*(1),. https://doi.org/10.47709/brilliance.v4i1.4231

[16] Rochman, H. A., Primananda, R., & Nurwasito, H. (2017). Sistem Kendali Berbasis Mikrokontroler Menggunakan Protokol MQTT pada Smarthome. ***Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer***, *1*(6).