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THE DEVELOPMENT OF AN IOT-BASED AUTOMATED TEMPERATURE AND PH MONITORING SYSTEM TO ENHANCE THE MANAGEMENT OF GOURAMI FISH PONDS

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ABSTRACT

This research aims to develop an Internet of Things (IoT)-based automated system for monitoring temperature and pH in the context of gourami fish farming. Gourami fish ponds are often situated in various environments with significant variations in environmental conditions. The system is designed to enable pond owners to remotely monitor real-time water temperature and pH, which are key factors in maintaining optimal water quality and fish health. The temperature sensor used is the DS18B20, while the pH sensor used is the E210C. The ESP32 platform is employed due to its integrated Wi-Fi capabilities. Monitoring displays are accessible on an LCD, personal computer (PC), and smartphone. This research involves the calibration and validation of temperature and pH sensors to ensure accurate measurements. The average standard deviation value for the temperature sensor is 0.092, and for the pH sensor, it is 0.031. The average accuracy of the temperature sensor is 98.60%, while the pH sensor has an average accuracy of 98.41%. The results demonstrate that IoT-based temperature and pH monitoring allow for in-depth data analysis of environmental conditions and long-term trend analysis in pond management.

Keywords: IoT, temperature, pH, gourami farming, monitoring.

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1. INTRODUCTION

The maintenance of gourami fish in aquaculture systems requires special attention to the environmental conditions of the pond, especially water temperature and pH [1], [2]. Optimal water quality is key to the healthy growth and productivity of gourami fish [3]. Uncontrolled decreases in temperature and pH can lead to stress in fish, decreased growth, and even diseases [4]. Therefore, continuous monitoring and proper control of water temperature and pH are crucial to the successful cultivation of gourami fish.

IoT-based monitoring of temperature and pH is an innovative approach that has transformed the traditional paradigm of water quality monitoring in fish farming and aquatic ecosystems [5]. Monitoring water quality in fish farming and aquatic ecosystems plays a very important role in maintaining the health of fish and environmental sustainability [6]. Optimal water quality, including stable temperature, appropriate pH levels, and other parameters such as dissolved oxygen, ammonia, and nitrate, are key factors in fish growth and development [7]. Careful and continuous monitoring helps pond owners detect changes that can threaten fish health, such as sudden temperature increases or extreme pH changes. On the other hand, in larger aquatic ecosystems, water quality monitoring provides insights into ecosystem conditions, pollution, and the impacts of climate change [8].

IoT technology allows us to monitor water temperature and pH in real-time from a distance [9], providing in-depth insights into environmental changes that can affect fish health and aquatic ecosystems. IoT technology has brought significant changes to understanding and managing aquatic environments and fish farming [10]. By utilizing temperature and pH sensors connected in real-time to the internet, the ability to monitor water conditions in fish ponds or wider aquatic ecosystems remotely. Continuously collected data allows us to detect changes that may not be visible to the naked eye or through periodic monitoring [11]. With a better understanding of aquatic environmental dynamics, we can take timely actions to maintain optimal water quality, support healthy fish growth, and preserve the important balance of aquatic ecosystems for environmental sustainability.

IoT-based monitoring of temperature and pH also assists in collecting consistent data, which can be used for long-term trend analysis and better decision-making in pond management [12]. Long-term trend analysis in pond management is a critical aspect of optimizing production outcomes and ensuring the sustainability of fish farming [1]. By continuously collecting data on temperature, pH, and other environmental parameters, pond owners can identify evolving patterns and trends over time. This allows them to make better decisions based on historical data, such as determining the right time for harvesting or planning corrective actions if there are continuous fluctuations in temperature or pH [13]. Trend analysis can also reveal the impacts of climate change or specific farming practices on fish health and pond productivity [14]–[18]. With a deeper understanding of long-term trends, pond managers can optimize their cultivation practices sustainably, improving efficiency and reducing risks.

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Several previous studies have not addressed how to adapt versatile IoT technology to be more suitable for various gourami fish farming environments, including different climate zones [7]. Gourami fish farming is a diverse practice and is often found in various locations with varying environmental conditions. Gourami fish are highly adaptable species and can be found in various aquatic ecosystems, such as ponds, rivers, and lakes [1]. Gourami fish farming can be found in different countries with significant geographical differences. Environmental conditions such as water temperature, pH levels, water resources, and climate can vary significantly between farming locations. Therefore, the adaptability of gourami fish and a deep understanding of environmental variability are key factors in successful fish farming practices [10].
Several previous studies have been conducted in efforts to calibrate and validate temperature and pH sensors for various applications, including fish farming [14]. However, it is important to note that each development of temperature and pH sensor devices requires specific calibration and validation to ensure the accuracy and consistency of measurements. The main reason is that different environmental and farming conditions can impact the characteristics of sensors and their response to changes in temperature and pH [6]. Water quality, chemical composition, ambient temperature, and other factors can vary significantly between farming locations [4]. Therefore, precise and location-specific calibration and validation are critical steps to ensure accurate and reliable measurement results. This also underscores the need for a sustainable approach to sensor monitoring and maintenance over the operational period to avoid changes in sensor response over time.

This research will focus on the design, calibration, validation, and testing of an automation system that can be effectively implemented to improve gourami fish pond management. This research has significant benefits and important reasons in the context of gourami fish farming and IoT-based water quality monitoring. With continuous monitoring of temperature and pH, pond owners can quickly detect environmental changes, allowing for timely corrective actions. In-depth data analysis also provides insights into long-term trends that can help plan more efficient farming. The importance of this research lies in its ability to enhance sustainable fish farming practices, empower farmers, and protect aquatic resources. With advanced IoT technology integration, this research can pave the way for innovation in fish farming and better aquatic resource management in the future.

2. THE METHOD

2.1 Electronic Components

The temperature sensor used is DS18B20. With its wide temperature range, DS18B20 is suitable for various applications that require temperature monitoring in diverse conditions, ranging from low to high temperatures [19]. The advantage of a single-wire interface is that it makes it easy to connect and integrate multiple sensors into one system, reducing cable clutter [20]. Furthermore, this sensor exhibits very low power consumption when inactive, rendering it ideal for battery-powered applications or those necessitating energy efficiency [21]. The E210C sensor is a pH sensor engineered with advanced technology, allowing for rapid response to changes in pH within the environment [22]. This sensor is often equipped with corrosion-resistant coatings, rendering it resistant to aggressive environments, thereby extending the sensor's lifespan and reducing maintenance costs. ESP32 is employed because it provides dependable Wi-Fi connectivity, enabling real-time monitoring of temperature, pH, and other water conditions within the fish pond [23]. Additionally, ESP32 is relatively cost-effective and user-friendly, facilitating cost-efficient IoT integration in fish farming [24]. Its capability to transmit data to cloud platforms or mobile applications also streamlines efficient monitoring and control of the fish pond, making it an extremely valuable choice for optimizing fish farming practices and enhancing water quality.

2.2 Research Design

The input pin of the DS18B20 sensor is connected to the GPIO4 pin on the ESP32 microcontroller. A 4700-ohm resistor is placed between the input pin and VCC. The input pin of the E201C pH sensor is connected to the GPIO33 pin of the ESP32 microcontroller. This sensor requires a 3.3V power supply, which is available on the ESP32 microcontroller. The 12x6 I2C LCD has SDA and SCL pins, which will be connected to the GPIO21 and GPIO22 pins of the ESP32 microcontroller. Both of these components require a 5V power supply from the ESP32 microcontroller. All of them are assembled and enclosed within a black box, as shown in Figure-1.

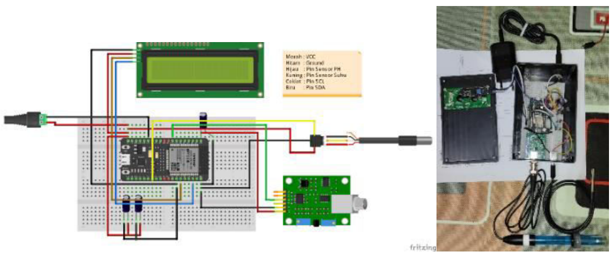

Figure-1. Electronic scheme.

2.3 Procedures

Calibrating and validating temperature and pH sensors are crucial processes in using sensors for temperature and pH monitoring in gourami fish ponds based on IoT [25]. Calibration establishes the relationship equation between the sensor's output and the measured quantity [26]. Good water quality and fish health rely heavily on accurate data. Validation is conducted to verify the sensor's output against reference instruments [27]. Validation data will be processed to generate sensor characteristics, which are precision and accuracy levels. Precision levels are commonly determined using the

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standard deviation formula, as shown in Equation 2. Sensor accuracy is determined using Equation 3 [28].

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{Xi} \tag{1}$$

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{x})^2}{n-1}} \tag{2}$$

$$\%\text{Accuracy} = 100\% - \left|\frac{\text{reference}-\text{sensor}}{\text{reference}}\right| \text{x } 100\% \tag{3}$$

where "$\bar{x}$" is the average, "SD"is the standard deviation, "Xi" is the i-th sample, and "n" is the amount of data.

3. RESULT AND DISCUSSION

3.1 Calibration and Validation

The monitoring results of temperature and pH in the gourami fish pond are displayed in Figure-2. The measurement results can be viewed through three displays, namely the LCD located at the pond, a PC, and a remotely accessible smartphone. Figure-3 shows the regression graph between the sensor outputs and their references. The x-axis represents the sensor-measured results, and the y-axis represents the measurement results using the reference instrument. It can be observed that the temperature sensor's output has an equation of $y = 0.9971x + 3.1839$ with an $R^2 = 0.9988$. This indicates that the data's fit to this equation is 99.88% [29]. The pH sensor calibration results in an equation of $y = -4.629x + 19.375$ with an $R^2 = 0.9921$. This demonstrates that the data fit to this equation is 99.21%. These values are excellent, as they are above 95% [30].

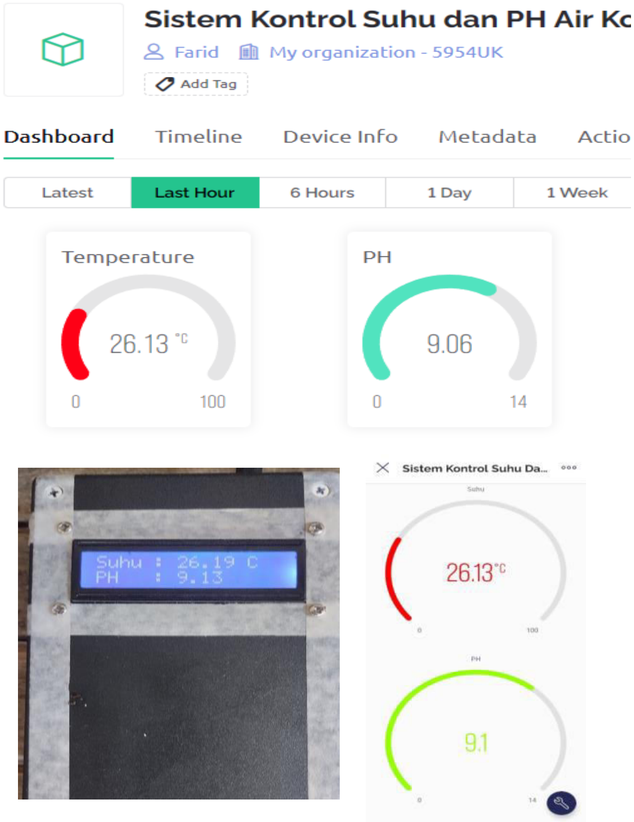

Figure-2. Measurement display on PC, LCD, and smartphone.

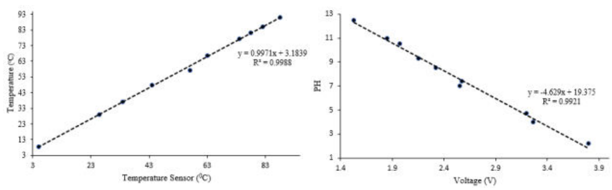

Figure-3. Calibrate temperature and pH sensors.

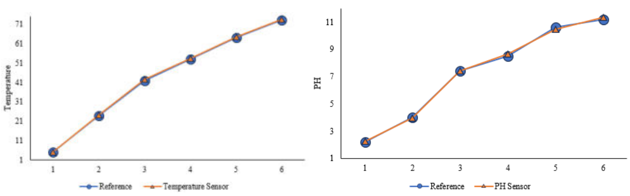

Figure-4. Validation of temperature and pH sensors.

The regression equations from the sensor calibration results are used to program the ESP32. After uploading the program, the sensor output results need to be validated. This validation is carried out to determine the sensor's characteristics during measurements. During the validation process, the standard deviation and sensor accuracy will be determined [31]. Figure-4 shows the validation results of temperature (a) and pH (b) sensor measurements. The blue color represents the measurement results obtained from the reference instrument, and the orange color represents the measurements made by the sensor. In the figure, it can be observed that the reference

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instrument's measurement results closely align with the sensor's measurement results. This indicates that the measurements taken by both are very similar or nearly identical. Sensor validation ensures that the sensors function correctly and provide consistent data [32].

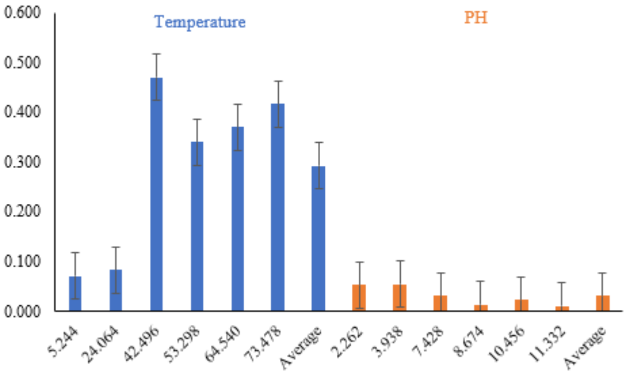

Figure-5. Distribution of standard deviation values.

Figure-5 represents the distribution of standard deviation values in each measurement. The standard deviation values vary significantly in each measurement. The blue color represents the standard deviation of temperature sensor measurements. The average standard deviation value for temperature sensors is 0.092. The orange color represents the standard deviation of pH sensor measurements. The average standard deviation value for pH sensors is 0.031. The standard deviation reflects the proximity of these values to their averages. A smaller standard deviation value indicates lower data variability, and the average value closely represents the data [33]. However, if the standard deviation value is high, the data spread will be larger and farther from its average value.

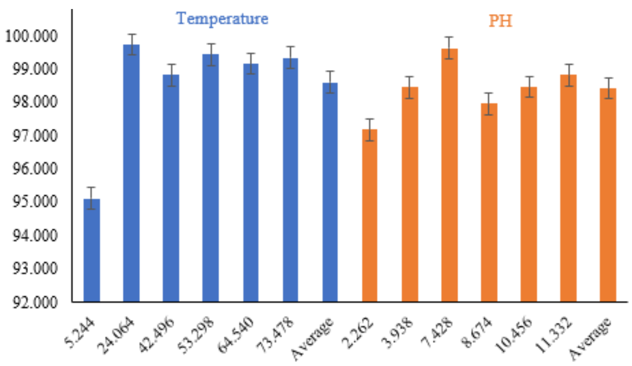

Figure-6. Distribution of accuracy values.

Figure-6 illustrates the distribution of accuracy values in sensor measurements. Digital scales were used as reference instruments to determine accuracy values. The load cell accuracy values are almost identical. The blue color represents the accuracy of temperature sensor measurements. The average accuracy value for temperature sensors is 98.60%. The orange color represents the accuracy of pH sensor measurements. The average accuracy value for pH sensors is 98.41%. Accuracy percentage is a measure of the precision and accuracy of measurement values compared to the true values [34]. Accuracy primarily emphasizes the measurement uncertainty of the created measuring instrument [35]. It also informs the level of measurement error that may occur with the measuring instrument. A higher accuracy value indicates that the measuring instrument is more precise and reliable.

3.2 Real-Time Monitoring of Temperature and pH

Real-time monitoring is one of the key features of the IoT-based temperature and pH monitoring system in fish ponds [10]. It refers to the system's ability to collect, process, and present water condition data directly and without delay. In the context of gourami fish pond maintenance, real-time monitoring offers significant benefits. Real-time monitoring allows for early detection of significant changes in water temperature and pH [36]. When water conditions approach unsafe thresholds, the system can provide automatic alerts to pond owners, enabling them to take immediate action to maintain optimal water quality.

Figure-7. The monitoring process on gourami ponds.

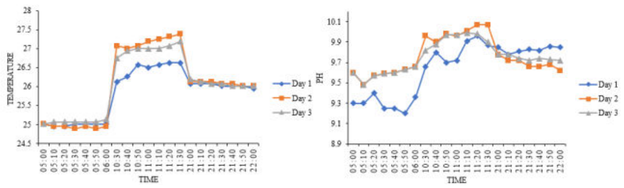

Figure-8. Monitoring suhu dan pH real-time.

The collected data can also be used to detect abnormal changes in temperature or pH [37]. This can be a sign of issues in the pond, such as equipment malfunctions or water pollution. This data includes key water health parameters that directly impact the fish's health [6]. Regular and real-time monitoring like this helps pond owners maintain water conditions within safe and optimal limits for gourami fish. With careful monitoring and a better understanding of the environmental conditions, pond owners can create an environment that supports better fish health, faster growth, and higher productivity in gourami fish farming [3].

Remote monitoring is a key feature of the IoT-based temperature and pH monitoring automation system in gourami fish ponds. It allows pond owners to monitor and control pond conditions remotely, offering several significant benefits, such as access from anywhere and rapid responses to changes [36]. Remote monitoring also reduces the need for on-site visits, saving time and energy. Additionally, monitoring data is stored in the system, enabling better analysis by observing trends through historical data [22].

CONCLUSIONS

This research highlights the importance of developing an IoT-based automation system for temperature and pH monitoring to improve the management of gourami fish ponds. The average accuracy of temperature sensors is 98.60%, and the average accuracy of pH sensors is 98.41%. With continuous temperature and pH monitoring, significant changes can be quickly detected, and corrective actions can be taken efficiently. The data collected by this system allows pond owners to conduct long-term trend analysis, aiding in more efficient fish farming planning based on historical data.

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