Design and Development of an IoT-Based Temperature and Ammonia Gas Detector Using Fuzzy Logic for Broiler Chicken Coops

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Abstract— **Temperature, humidity, and ammonia gas are critical factors that affect the health and productivity of broiler chickens. Manual monitoring commonly carried out by farmers is inefficient and prone to errors, thus requiring an automatic system capable of real-time detection. This study developed a monitoring system for temperature, humidity, and ammonia levels in broiler chicken coops based on the IoT using the Sugeno fuzzy logic method. The system was designed with a NodeMCU ESP8266 microcontroller integrated with a DHT22 sensor for temperature and humidity, and a MQ-135 sensor for ammonia gas. Measurement data are displayed in real time through an LCD, Blynk application, and ThingSpeak allowing remote monitoring. The decision-making process is carried out using Sugeno fuzzy logic to classify coop conditions into safe, alert, or danger. Experimental results show MAPE values of 2,7% for temperature and 3,5% for humidity. The system operated continuously for 14 days and generated 1,265 consistent monitoring data points. Thus, the proposed system assists in automatic coop monitoring and supports increased broiler chicken productivity.**

Keywords: Broiler chicken, DHT22, Fuzzy Sugeno, IoT, NodeMCU ESP8266

I. INTRODUCTION

Growth and productivity of chickens are greatly influenced by environmental conditions, particularly temperature, humidity, and air quality inside the coop. In tropical countries such as Indonesia, managing coop temperature is crucial since chicks require an environment below 30˚C [1]. Chickens' inability to regulate their body temperature in hot environments can trigger heat stress, which is affected by high temperature, humidity, and air circulation, with temperature being the most dominant factor [2]. This condition results in increased water intake, decreased feed consumption, watery feces, reduced productivity, and even mortality. In addition, coop air quality also plays an important role in maintaining chicken health, one aspect which is influenced by the concentration of ammonia gas (NH_3) measured in parts per million (ppm) [3].

Broiler chickens are poultry with high productivity due to their rapid growth and ability to be harvested within 5-7 weeks. This advantage is influenced by genetic factors as well as environmental conditions such as temperature, maintenance, and feed, where broiler meat consumption ranked the highest compared to other types of meat during 2019-2023. Temperature regulation in the coop, particularly during the brooding phase is a determining factor for achieving optimal production performance. The utilization of control systems and temperature sensors enables precise regulation according to the chickens' needs; therefore, special attention to this aspect is crucial since failure during the brooding phase cannot be corrected in subsequent growth stages [4].

The recommended rearing temperature for broiler chickens is 30-32˚C at 0 days of age, 28-30˚C at 7 days, 25-27˚C at 14 days, and 22-24˚C at 21 days, with an optimal humidity range of 30-70%. The increase in the number of poultry farmers in Indonesia has led to problems in managing manure waste that produces ammonia gas, thereby potentially polluting the air due to microbial activity. The safe concentration of ammonia for chickens ranges from 20 to 25 ppm, while a level of 25 ppm can still be tolerated for up to 8 hours [5].

Previous studies have shown that the fuzzy method is effective in controlling temperature, humidity, and air quality in poultry houses. A fuzzy Mamdani-based control system with NodeMCU ESP832 was successfully developed to regulate fans [6], while the application of Sugeno fuzzy logic with NodeMCU ESP8266 was used to control fans and pumps based on temperature, humidity, and chicken age [7]. A monitoring system for temperature, humidity, and lighting was also designed using DHT22 and LDR sensors with fan and lamp actuators [8]. Ammonia gas control based on Matlab with MQ-135 and DHT11 sensors achieved an accuracy of over 97%, and monitoring integration through the Blynk app and ThingSpeak [9]. Other studies have shown that both Sugeno and Mamdani fuzzy methods are capable of cntrolling actuators and monitoring coop parameters with low sensor error rates, thus proving the effectiveness of fuzzy logic in poultry house environmental management [10][11].

Based on these issues, this study aims to design a detection system for temperature, humidity, and ammonia gas levels ini poultry houses using the Internet of Things (IoT) with the Sugeno fuzzy method. The system is developed using a NodeMCU ESP8266 microcontroller supported by a DHT22 sensor for measuring temperature and humidity, and an MQ-135 sensor for detecting ammonia gas. Measurement data are displayed through an LCD, Blynk app, and ThingSpeak, allowing real-time and remote monitoring. With this design, the system is expected to provide an efficient and accurate solution for monitoring coop conditions and supporting the improvement of broiler chicken productivity.

II. METHOD

In general, the stages of this research can be illustrated through the following flowchart.

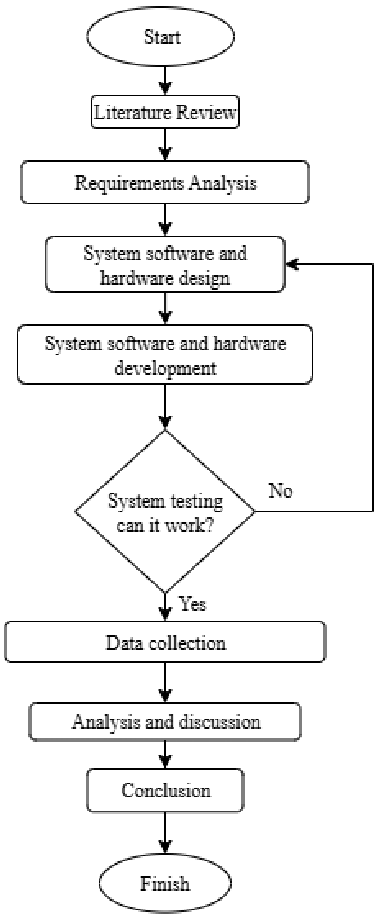

Figure 1. Research Flowchart

A. Literature Review

Collect references from journals related to temperature, humidity, and ammonia detection systems based on IoT using fuzzy methods, in order to identify the strengths and weaknesses of previous studies.

B. Requirements Analysis

Determine the specifications of the designed system, such as the ability to operate continuously, sensor accuracy with a tolerance of ≤10%, and adaptability to changes in temperature, humidity, and ammonia levels in the chicken coop.

System Software and Hardware Design and Development

C. Hardware/IoT Design

The main system circuit consists of the NodeMCU ESP8266, DHT22 sensor, MQ-135 sensor, 16×2 LCD, and exhaust fan. The system circuit is shown in Figure 2.

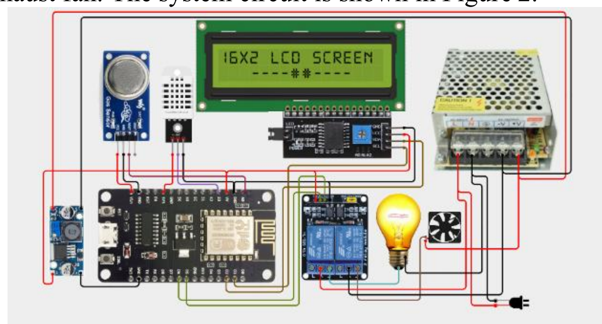

Figure 2. Overall System Circuit

D. Fuzzy Design

Fuzzy logic is a computational method that uses linguistic variables to replace numerical variables, allowing it to handle complex problems more flexibly [12]. This system can operate automatically at a level equivalent to manual control, with a simple structure, robustness, and the ability to function in real-time [13]. In this study, fuzzy logic is designed with inputs of temperature, humidity, and ammonia gas levels, and an output in the form of coop conditions (safe, alert, or dangerous) as the basis for actuator control. For the temperature input variable, there are three linguistic variables [14]:

$$\mu_{cold}[x] = \begin{cases} 0;\ x \geq 23 \\ \frac{23-x}{23-21};\ 21 < x < 23 \\ 1;\ x \leq 21 \end{cases} \quad (1)$$

$$\mu_{normal}[x] = \begin{cases} 0;\ x \leq 21\ and\ x \geq 30 \\ \frac{x-23}{23-21};\ 21 < x < 23 \\ \frac{30-x}{30-27};\ 27 < x < 30 \\ 1;\ 23 \leq x \leq 27 \end{cases} \quad (2)$$

$$\mu_{hot}[x] = \begin{cases} 0;\ x \leq 27 \\ \frac{x-27}{30-27};\ 27 < x < 30 \\ 1;\ x \geq 30 \end{cases} \quad (3)$$

The fuzzy membership function for temperature can be represented by the graph in Figure 3.

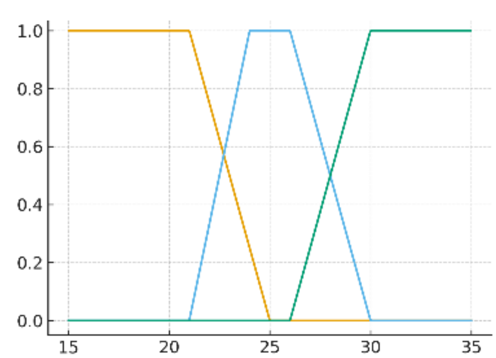

Figure 3. Temperature Membership Function Graph

For the humidity input, there are three linguistic variables [14]:

$$\mu_{dry}[x] = \begin{cases} 0;\ x \geq 40 \\ \frac{40-x}{40-30};\ 30 < x < 40 \\ 1;\ x \leq 30 \end{cases} \quad (4)$$

$$\mu_{moist}[x] = \begin{cases} 0;\ x \leq 30\ and\ x \geq 70 \\ \frac{x-30}{40-30};\ 30 < x < 40 \\ \frac{70-x}{70-60};\ 60 < x < 70 \\ 1;\ 40 \leq x \leq\ 60 \end{cases} \quad (5)$$

$$\mu_{wet}[x] = \begin{cases} 0;\ x \leq 60 \\ \frac{x-60}{70-60};\ 60 < x < 70 \\ 1;\ x \geq 70 \end{cases} \quad (6)$$

The fuzzy membership function for humidity can be represented by the graph in Figure 4.

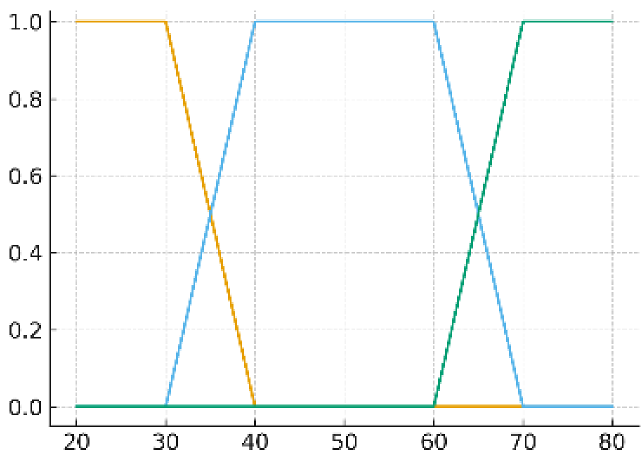

Figure 4. Humidity Membership Function Graph

For the ammonia gas input, there are three linguistic variables:

$$\mu_{normal}[x] = \begin{cases} 0;\ x \geq 20 \\ \frac{20-x}{20-15};\ 15 < x < 20 \\ 1;\ x \leq 15 \end{cases} \quad (7)$$

$$\mu_{moderate}[x] = \begin{cases} 0;\ x \leq 15\ and\ x \geq 30 \\ \frac{x-15}{20-15};\ 15 < x < 20 \\ \frac{30-x}{30-25};\ 25 < x < 30 \\ 1;\ 20 \leq x \leq\ 25 \end{cases} \quad (8)$$

$$\mu_{high}[x] = \begin{cases} 0;\ x \leq 25 \\ \frac{x-25}{30-25};\ 25 < x < 30 \\ 1;\ x \geq 30 \end{cases} \quad (9)$$

The fuzzy membership function for ammonia gas can be represented by the graph in Figure 5.

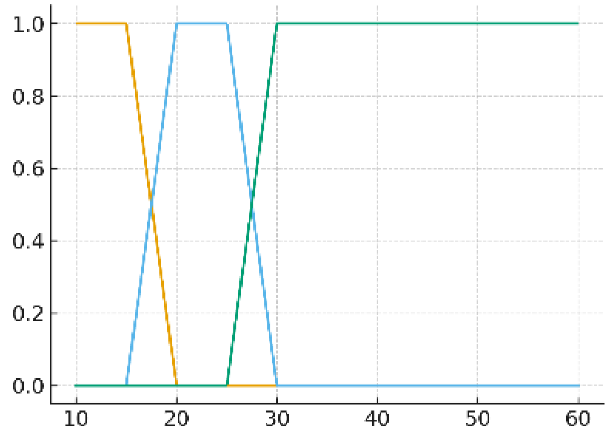

Figure 5. Ammonia Gas Membership Function Graph

After determining the input and output parameters, rules for the inference process are defined. In this system, 27 rules have been established, as presented in Table I.

TABLE I
FUZZY RULES IN THE DETECTION SYSTEM

No.	Temperature	Humidity	Ammonia	Coop Condition
1	Cold	Dry	Normal	Safe
2	Cold	Dry	Moderate	Alert
3	Cold	Dry	High	Alert
4	Cold	Moist	Normal	Safe
5	Cold	Moist	Moderate	Alert
6	Cold	Moist	High	Alert
7	Cold	Wet	Normal	Safe
8	Cold	Wet	Moderate	Alert
9	Cold	Wet	High	Alert
10	Normal	Dry	Normal	Safe
11	Normal	Dry	Moderate	Alert
12	Normal	Dry	High	Danger
13	Normal	Moist	Normal	Safe
14	Normal	Moist	Moderate	Alert
15	Normal	Moist	High	Danger
16	Normal	Wet	Normal	Safe
17	Normal	Wet	Moderate	Alert
18	Normal	Wet	High	Danger
19	Hot	Dry	Normal	Safe
20	Hot	Dry	Moderate	Danger
21	Hot	Dry	High	Danger
22	Hot	Moist	Normal	Safe
23	Hot	Moist	Moderate	Danger
24	Hot	Moist	High	Danger
25	Hot	Wet	Normal	Safe
26	Hot	Wet	Moderate	Danger
27	Hot	Wet	High	Danger

In the Sugeno method, the implication operator used is the additive (sum) method with the following equation:

$$\mu_h[x] = \min(1, \quad \mu_p[xi] + \mu_k[xi]) \quad (10)$$

where $\mu_h[x]$ represents the resulting value of the statement and the consequence of the fuzzy rule. The defuzzification process then uses the Weighted Average (WA) method with the following formula:

$$WA = \frac{\mu 1 z1 + \mu 2 z2 + \cdots + \mu n z n}{\mu 1 + \mu 2 + \cdots + \mu n} \quad (11)$$

Weighted Average is a way of calculating the average by assigning different weights to each value.

1) Experimental Setup

The device was installed in a closed chicken coop measuring 1×1 meters, containing 10 chicks. The coop was built from bamboo and plywood, as shown in Figure 6.

Figure 6. Front and Rear View of the Chicken Coop

At the front of the coop, the detection device was placed with its LCD visible, while at the back of the coop, the exhaust fan was installed.

The data collection period was carried out continuously for 24 hours over 14 days. Thus, the collected data could be monitored via a smartphone using the Blynk app. The data were then stored and visualized in graphs using ThingSpeak.

Testing and Data Collection

This testing ensures that the microcontroller program can receive data from the sensors and forward it to the LCD, Blynk app, and ThingSpeak. The accuracy of the DHT22 sensor for temperature and humidity measurement is tested using the HTC-1 Hygrometer measuring instrument.

Analysis and Discussion

TABLE II
MAPE VALUE CATEGORIES

Category	MAPE Value
Very Good	< 10 %
Good	10 – 20 %
Fair	20 – 50 %
Inaccurate	> 50 %

The data analysis process used a descriptive method. The accuracy level was calculated using the Mean Absolute Percentage Error (MAPE) and the overall performance of the detection system was evaluated [15]. MAPE can be calculated using the following equation:

$$MAPE = \frac{1}{n}\sum_{i=0}^{n}\left(\frac{\overline{X}1-\overline{X}2}{\overline{X}2}\right) \times 100\% \quad (12)$$

With $\overline{X}1$ representing the average value from the sensor and $\overline{X}2$ representing the average value from the conventional instrument, the MAPE value can be categorized into four groups as shown in Table II [16].

III. RESULT AND DISCUSSION

This detection system consists of a NodeMCU ESP8266, DHT22 sensor, MQ-135 sensor, LCD, exhaust fan, incandescent lamp, and relay, which are assembled according to the system circuit shown in Figure 2. The device assembly is presented in Figure 7.

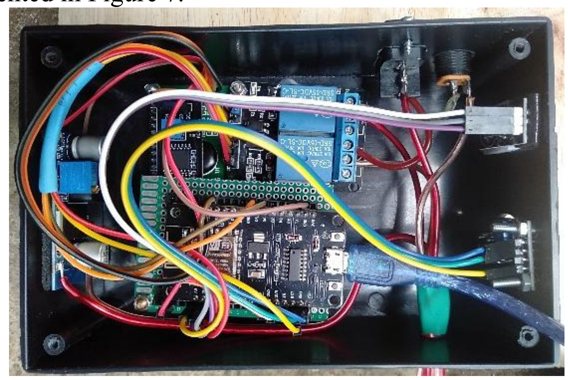

Figure 7. Detector Device Assembly

The detection device is powered by a power supply connected to an LM2596 regulator, which functions to reduce and stabilize the voltage in the system to ensure safety and prevent overvoltage.

The testing was carried out by comparing the results of the DHT22 sensor with the HTC-1 Hygrometer measuring instrument. The temperature testing results are shown in Table III.

TABLE III
TEMPERATURE TESTING DATA

Temperature Test (°C)	Measuring Instrument (Hygrometer HTC-1)	Error Percentage (%)
23,8	25	4,8
23,6	25	5,6
25,0	25	0,0
25,3	25	1,2
25,4	25	1,6
25,7	25	2,8
26,0	25	4,0
24,6	25	1,6
25,5	25	2,0
25,9	25	3,6
MAPE		2,7
Accuracy (100% - MAPE)		97,3

Subsequently, the humidity testing results are presented in Table IV.

TABLE IV
HUMIDITY TESTNG DATA

Humidity Test (%)	Measuring Instrument (Hygrometer HTC-1)	Error Percentage (%)
84	94	10,6
89	94	5,3
91	94	3,2
92	94	2,1
88	93	5,4
93	93	0,0
91	93	2,2
88	93	5,4
91	92	1,1
92	92	0,0
MAPE		3,5
Accuracy (100% - MAPE)		96,5

The DHT22 sensor showed a MAPE value of 2,7% for temperature and 3,5% for humidity. These MAPE values indicate that the sensor falls into the "very good" category according to the MAPE standard. During the 14-day data collection period, the system successfully recorded 1,265 coop condition data points. The calculation process used the Sugeno fuzzy method by categorizing coop conditions as safe, alert, or danger based on temperature, humidity, and ammonia gas values. The collected data demonstrated that the system was capable of providing consistent outputs in accordance with the fuzzy rules. The calculation using the Sugeno fuzzy method for each sample condition is as follows:

A. Fuzzification

The research data obtained were as follows:

1) *Safe Condition*
   Based on data collected on August 17, 2025 at 13:00, the temperature was 29°C, humidity was 69%, and ammonia gas was 3 ppm.
2) *Alert Condition*
   Based on data collected on August 20, 2025 at 19:30, the temperature was 29°C, humidity was 90%, and ammonia gas was 22 ppm.
3) *Danger Condition*
   Based on data collected on August 21, 2025 at 19:15, the temperature was 28°C, humidity was 90%, and ammonia gas was 26 ppm.

The fuzzification calculation is presented in Table V.

TABLE V
FUZZIFICATION CALCULATIONS

Coop Condition	Temperature	Humidity	Ammonia Gas
Safe	Normal $\mu[normal] = \frac{30-29}{30-27} = 0{,}33$	Moist $\mu[moist] = \frac{70-69}{70-60} = 0{,}1$	Normal $\mu[normal] = 1$
		Wet $\mu[wet] = \frac{69-60}{70-60} = 0{,}9$	
Alert	Normal $\mu[normal] = \frac{30-29}{30-27} = 0{,}33$	Wet $\mu[wet] = 1$	Moderate $\mu[moderate] = 1$
Danger	Normal $\mu[normal] = \frac{30-28}{30-27} = 0{,}67$	Wet $\mu[wet] = 1$	Moderate $\mu[moderate] = \frac{30-26}{30-25} = 0{,}8$
			High $\mu[high] = \frac{26-25}{30-25} = 0{,}2$

Inference

1) *Safe Condition, there are 2 active rules*
   [13] IF temperature is normal, humidity is moist, ammonia is normal THEN safe.
   μ (rule 13) = min (0,33, 0,1, 1) = 0,1
   [16] IF temperature is normal, humidity is wet, ammonia is normal THEN safe.
   μ (rule 13) = min (0,33, 0,9, 1) = 0,33
2) *Alert Condition, there are 1 active rule*
   [17] IF temperature is normal, humidity is wet, ammonia is moderate THEN alert.
   μ (rule 17) = min (0,33, 1, 1) = 0,33
3) *Danger Condition, there are 2 active rules*
   [17] IF temperature is normal, humidity is wet, ammonia is moderate THEN alert.
   μ (rule 17) = min (0,67, 1, 0,8) = 0,7
   [18] IF temperature is normal, humidity is wet, ammonia is high THEN danger.
   μ (rule 18) = min (0,67, 1, 0,2) = 0,2

B. Defuzzification

The defuzzification results show coop conditions as safe, alert, or danger, represented by the values z_1= 0 (safe), z_2= 1 (alert), and z_3= 2 (danger).

1) *Safe*

$$\mathrm{WA} = \frac{\sum \mu_{\text{rule }13}.z_1 + \mu_{\text{rule }16}.z_1}{\mu_{\text{rule }13} + \mu_{\text{rule }16}}$$

$$= \frac{0{,}1.0 + 0{,}33.0}{0{,}1 + 0{,}33} = \frac{0}{0{,}43} = 0$$

2) *Alert*

$$WA = \frac{\sum \mu_{\text{rule }17}.z_2}{\mu_{\text{rule }17}}$$

$$= \frac{0{,}33.1}{0{,}33} = \frac{0{,}33}{0{,}33} = 1$$

3) *Danger*

$$WA = \frac{\sum \mu_{\text{rule }17}.z_2 + \mu_{\text{rule }18}.z_3}{\mu_{\text{rule }17} + \mu_{\text{rule}18}}$$

$$= \frac{0{,}67.1 + 0{,}2.2}{0{,}67 + 0{,}2} = \frac{1{,}07}{0{,}87} = 1{,}23$$

In this study, based on fuzzy calculations, the lamp will always be on in all conditions. When the chicken coop is in a dangerous condition, the exhaust fan will turn on. Overall, the system was able to operate as intended and successfully monitor coop conditions automatically. The information was clearly displayed through the LCD, Blynk, and ThingSpeak, allowing remote data access. With high accuracy and continuous monitoring capability, this system is considered effective in supporting chicken coop environmental management. The Blynk app interface is shown in Figure 8.

Figure 8. Blynk App Display

The visualization of data in graphs on ThingSpeak is shown in Figures 9 and 10.

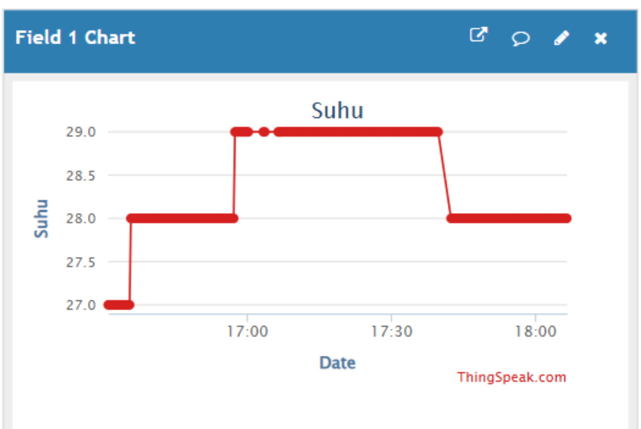

Figure 9. Temperature Data Reading Graph

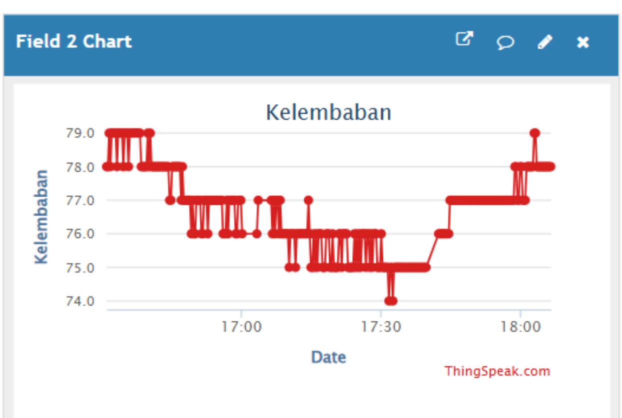

Figure 10. Humidity Data Reading Graph

The test results show that the temperature and ammonia gas detection system developed using the Sugeno fuzzy logic method can operate in real time within a 1 m × 1 m × 1 m chicken coop containing ten 3-day-old chicks. The experiment was conducted for 14 days in real time and successfully collected a total of 1,265 data points.

Data obtained from the DHT22 and MQ-135 sensors were transmitted in real time to ThingSpeak via the internet as the data communication medium. The stored data on ThingSpeak were then forwarded to the Blynk application to display the outputs of both sensors and the system's environmental condition decisions. Based on the fuzzy logic decision results, the actuator control operated as follows: in *Safe* and *Alert* conditions, only the lamp was activated, while in *Danger* conditions both the lamp and the exhaust fan were activated simultaneously.

During the 14-day data acquisition period, the coop temperature generally remained within the normal range, the humidity level tended to fall within the wet category, and the ammonia concentration remained at a normal level. Humidity could be reduced to the moist range with the assistance of the lamp heater; however, this process required approximately 10–15 minutes to produce a significant effect. The lamp heater proved insufficient for rapidly reducing humidity, resulting in persistently high humidity levels for extended periods. Due to excessive humidity conditions, one chick died during the experiment. Thus, humidity control is a crucial aspect of the coop environmental management system, and a more effective heating mechanism is required to optimize humidity regulation.

IV. CONCLUSION

The IoT-based detection system for temperature, humidity, and ammonia gas using the Sugeno fuzzy method successfully operated in real time and demonstrated high accuracy in monitoring broiler chicken coop conditions, achieving MAPE values of 2,7% for temperature and 3,5% for humidity. Over 14 days of testing, the system generated 1,265 consistent data points and accurately classified coop conditions (safe, alert, danger) according to the established fuzzy rules. However, this study has several limitations, including suboptimal humidity control due to reliance on a single heating lamp, sensor sensitivity constraints, and testing conducted in a small-scale coop that does not fully represent real farm environments. Therefore, future research is recommended to incorporate more effective heating or dehumidification systems, employ additional and more accurate sensors and actuators, conduct experiments on larger-scale coops, and integrate advanced IoT and artificial intelligence approaches to enhance prediction capabilities and automated decision-making.

REFERENCES

[1] H. Supriyono, F. Suryawan, R. M. A. Bastomi, and U. Bimantoro, "Sistem Monitoring Suhu dan Gas Amonia untuk Kandang Ayam Skala Kecil", *ELKOMIKA Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika*, vol. 9, no. 3, pp. 562, 2021, doi: 10.26760/elkomika.v9i3.562.

[2] S. Wasti, N. Sah, and B. Mishra, "Impact of heat stress on poultry health and performances, and potential mitigation strategies", *Animals*, vol. 10, no. 8, pp. 1–19, 2020, doi: 10.3390/ani10081266.

[3] R. Fatahillah Murad, G. Almasir, C. Ronald Harahap, T. Komputer, and L. Ratu, "Pendeteksi Gas Amonia Untuk Pembesaran Anak Ayam Pada

Box Kandang Menggunakan MQ-135", *Jurnal Ilmiah Mahasiswa Kendali dan Listrik*, vol. 3, no. 1, pp. 120–130, 2022.

[4] F. Hidayat, S. Sumiati, R. Afnan, and R. Fadilah, "Pengaturan Suhu Brooding pada Performa Ayam Broiler Pelanggan PT New Hope Indonesia", *Jurnal Ilmu Pertanian Indonesia*, vol. 28, no. 4, pp. 599–606, 2023, doi: 10.18343/jipi.28.4.599.

[5] R. N. Wakidah, S. Z. N. Haq, Y. A. Andrianto, and A. M. Damayanti, "Pemodelan Sistem Monitoring dan Kontrol Kadar Gas Amonia pada Kandang Ayam sebagai Upaya Meningkatkan Kesehatan dan Kualitas", *JTEIN Jurnal Teknik Elektro Indonesia*, vol. 5, no. 1, pp. 22–31, 2024, doi: 10.24036/jtein.v5i1.579.

[6] A. F. Trinaldi, "Sistem Kontrol dan Monitoring Suhu Kelembaban Kandang pada Peternakan Ayam Broiler dengan Metode Logika Fuzzy Mamdani Berbasis Internet of Things", *Prosiding Sains Nasional dan Teknologi*, vol. 12, no. 1, pp. 349, 2022, doi: 10.36499/psnst.v12i1.7046.

[7] D. Suprianto, E. Pristiya, and A. Prasetyo, "Smart Chicken Coop Ecosystem for Optimal Growth of Broiler Chickens Using Fuzzy on IoT", *Inform: Jurnal Ilmiah Bidang Teknologi Informasi dan Komunikasi*, vol. 7, no. 1, pp. 16–23, 2022, doi: 10.25139/inform.v7i1.4231.

[8] Dewi Raokhil Iklima Fariyya, "Rancang Bangun Monitoring Suhu, Kelembaban, Dan Intensitas Cahaya Pada Kandang Ayam Berbasis Web", *Walisongo Instituonal Repository*, pp. 26, 2020.

[9] M. Fatahilah, Nasri, "Rancang Bangun Prototype Pengendali Gas Amonia Pada Peternakan Ayam Broiler Berbasi Iot", *Jurnal Tektro*, vol. 7, no. 2, pp. 234–239, 2023.

[10] C. E. Wulandari, I. Nawawi, and A. A. Kurniawan, "Perancangan Sistem Kendali Fuzzy Pada Prototipe Kandang Ayam Broiler Tipe Close House", *THETA OMEGA Jurnal of Electrical Engineering*, 2023.

[11] P. Adi Sudarmawan, A. Panji Sasmito, and R. Primaswara, "Penerapan Logika Fuzzy Pada Sistem Monitoring Dan Kontrol Kandang Ayam Otomatis Berbasis IoT", *JATI (Jurnal Mahasiswa Teknik Informatika*, vol. 5, no. 1, pp. 315–320, 2021, doi: 10.36040/jati.v5i1.3265.

[12] K. Gunawan, 'Wind Power Hybrid Power Generation System Controller - PMSG With Fuel Cell Using Fuzzy Logic Controller", *Journal Geuthee Engineering and Energy (JOGE)*, vol. 2, no. 2, pp. 93–105, 2023, doi: 10.52626/joge.v2i2.29.

[13] M. Santo Gitakarma, L. Putu Ary Sri Tjahyanti, and P. Korespondensi, "Perbandingan Kinerja Sistem Monitoring Dan Kontrol Iot Berbasis Fuzzy Logic Dengan Kontrol Manual Dalam Model Skala Kecil Comparison of Iot-Based Monitoring and Control System Performance Using Fuzzy Logic and Manual Control in a Small-Scale Model", *Jurnal Komputer dan Teknologi Sains (KOMTEKS)*, vol. 3, no. 1, pp. 23–28, 2024.

[14] Cobb, "COBB Broiler Management Guide", *Cobb-vantress Inc.*, pp. 1–69, 2021.

[15] A. P. Hajar, S., Badawi, M., Setiawan, Y. D., Siregar, M. N. H., & Windarto, "Prediksi Perhitungan Jumlah Produksi Tahu Mahanda dengan Teknik Fuzzy Sugeno", *J-SAKTI (Jurnal Sains Komputer dan Informatika*, vol. 4, no. 1, pp. 210–219, 2020.

[16] M. Ema Julpia Aenun, "Implementasi Logika Fuzzy Metode Mamdani Pada Prediksi Biaya Pemakaian Listrik", *UNNES Journal of Mathematics*, vol. 11, no. 2, pp. 179–188, 2022.