Design and Implementation of Server Room Controlling using the Fuzzy Sugeno Method

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DOI: https://doi.org/10.31284/j.jtm.2024.v5i2.4653
Received 26 June 2023; Received in revised 25 July 2023; Accepted 2 August 2023; Available online 20 May 2024

Abstract

The security standard for the server room is highly needed, as it is used as a place to store servers, network devices (routers, hubs, switches), and other equipment. A good server room includes monitoring processes for humidity, temperature, and smoke levels. Therefore, a device capable of real-time controlling and online access using Internet of Things (IoT) technology based on Wemos D1 R2, DHT22 sensor, MQ2 sensor, and infrared sensor is required. Each DHT22 sensor has uncertainty in temperature measurement, with the DHT22 sensor (∑) obtaining a repeated measurement uncertainty value of 0.22%, DHT22 sensor (Δ) 0.22%, and DHT22 sensor (α) 0.50%. Additionally, the level of uncertainty in humidity measurement for each DHT22 sensor is (∑) 1.85%, DHT22 sensor (Δ) 2.22%, and DHT22 sensor (α) 4.80%. An important aspect of this research is the implementation of the fuzzy Sugeno method to regulate the operation of the AC based on temperature and humidity data, where the system can make appropriate decisions according to the server room's environmental conditions. Subsequently, an analysis and implementation of ISO:27001 as a security standard are conducted for the server room at Institut Teknologi Kalimantan, maintaining the temperature between 20-25°C and humidity between 40-55%. However, there is a discrepancy between the device's temperature and humidity readings and the thermometer used. Thus, it is necessary to adjust the temperature membership range to 18-27°C and humidity to 40-80%. Finally, a threshold of 2196.8383 ppm is set for the MQ2 sensor to detect the presence of smoke on a small scale.

Keywords: *Fuzzy Sugeno, Humidity, Server Room, Smoke Content, Temperature, Threshold*

1. 1. Introduction

Rapidly developing technology has an influence on daily human activities. Apart from communicating, technology has an increasingly widespread role, resulting in new innovations emerging in human life, including human communication with devices connected to the internet. This innovation is known as the application of Internet of Things (IoT) technology [1], [2]. The concept of expanding the benefits of the internet in bridging communication between devices and humans is one of the concepts of the Internet of Things (IoT), which allows humans to monitor, operate and manage devices connected to the internet network even at quite long distances [3], [4].

In an agency, there is a server room that stores server computers, network devices such as (routers, hubs, switches) and other devices. Special attention and good care is needed in server room security. In the server room, to protect existing devices from air temperature, humidity, and fire, server room security standards are needed [5], [6].

The Kalimantan Institute of Technology became one of the institutions in the field of education. The Kalimantan Institute of Technology has a server room which functions to store servers, network devices (hubs, switches, routers) as well as other devices in the operational system. In the server room there is several hardware whose performance can be affected by temperature and humidity. The Directorate General of Taxes, Ministry of Finance of the Republic of Indonesia issued

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Circular Letter Number SE-16/PJ/2011 entitled "Guidelines for Safeguarding Data and Information Processing Devices and Facilities". This guideline refers to the Telecommunications Industry Association (TIA) 942 and ISO/IEC 27001:2005 standards, specifically regarding the recommended temperature and humidity specifications for server rooms, namely 20-25°C for temperature, and 40-55% for relative humidity [7], with smoke levels of 350 ppm – 1000 ppm [8]. If the temperature in the server room is too low, it can result in a decrease in device performance and disrupt its working mechanism. On the other hand, temperatures that are too high can cause overheating of the components in the room, which has the potential to damage these components. In addition, if there are high levels of smoke, it can trigger the risk of fire in the server room.

Until now, quite a lot of research has been carried out which has led to this problem, one of which is "Monitoring Server Room Temperature Using Fuzzy Logic Sugeno Method Using Arduino and SMS" which was carried out by Abdullah and Wibowo. In this research, Sugeno's Fuzzy Logic Method [9] was used. Furthermore, research was conducted by Orlando, Kaparang, Santa entitled "Design of a Server Room Temperature Control System Using Arduino Uno at the Manado State University Computer Center". Based on the results obtained, the server room administrator can monitor the server room anytime and anywhere via telegram, then the system will automatically provide output in the form of on/off the AC according to the conditions in the server room [10]. After that, research was carried out by Siswanto, Firdiansyah, Anif, Prasetyo entitled "Server Room Control and Monitoring with DHT11 Sensors, MQ-2 Gas and SMS Notifications". Based on the results obtained, the server administrator can monitor the temperature and gas in the server room anywhere. Based on observations during 23 days of testing, this application was successful in providing 98% of notifications and only experienced 2% failures [11].

The Server Room at the Kalimantan Institute of Technology is currently not equipped with real-time monitoring tools or systems for temperature, humidity and smoke levels. As a result, administrators must directly monitor the temperature, humidity, and smoke levels in the server room, which is not feasible continuously for 24 hours. To overcome and minimize damage to the server room, a monitoring system is needed that can monitor the condition of the server room in real-time. This system will provide output regarding AC status (on/off) based on the detected server room conditions. Monitoring is carried out on temperature, humidity and smoke levels in the server room in real-time. This research uses the Fuzzy Sugeno method to determine the output related to when the AC should be turned on and off. Thus, this system aims to maintain optimal conditions in the server room with information obtained in real-time.

2. Method

The method used in this research is the fuzzy Sugeno method [12]. This method has three main processes, namely fuzzification, inference/reasoning, and defuzzification. Here, the process of the proposed method is presented in Figure 1, where the initial stage, determining the linguistic values and their input variables, is then obtained for the definition of the membership function and will be combined with a fuzzy series that already has a membership function. Then, the input value calculation process is done by forming membership degrees with membership function boundaries at the fuzzification stage. In the fuzzification stage, variables with firm values will be converted into fuzzy variables that have linguistic values. Next, the defuzzification stage will produce output values using different implications for each fuzzy method. Then, define output variables by analyzing and processing input data. Then, the input value calculation process is done by forming membership degrees with membership function boundaries at the fuzzification stage. In the fuzzification stage, variables with firm values will be converted into fuzzy variables that have linguistic values. Next, the defuzzification stage will produce output values using different implications for each fuzzy method. Then, define output variables by analyzing and processing input data.

2.1 Fuzzification

The input of the proposed method is the temperature and humidity conditions in the server room. temperature and humidity were chosen because they influence the conditions that determine the condition of the AC. The temperature variable consists of cold, normal and hot linguistic sets whose degrees of membership are shown in Figure 3(a). The humidity variable consists of dry, medium and wet linguistic sets whose degrees of membership are shown in Figure 3(b). The range of membership degrees is adjusted to the conditions in the server room and the system used. By using a triangular curve representation whose rules are defined in equation (1), where if x is less than or equal to a or x is greater than or equal to c, then the membership value is zero or is not a member of the set. If the value of x is between the value of a and the value of b, then the membership value can be calculated from the value of b as the upper limit minus the value of x then divided by the result of the reduction of value (b) as the upper value and value (a) as the lower limit. Meanwhile, if the x value is between the b value and the c value, then the membership value can be calculated from the upper limit value (c) minus the x value then divided by the result of the reduction of the upper limit (c) and lower limit (b) [13].

$$\mu(x) = \{0 \ (b-x)/(b-a) \ (c-x)(c-b) \quad x \leq a \ or \ x \geq c \quad a \leq x \leq b \quad b \leq x \leq c \tag{1}$$

The temperature variable membership function is used in fuzzy logic to determine the extent to which a value "x" is included in the "cold" fuzzy set with the range of values used, namely 0-18 shown in equation (2), for the "normal" fuzzy set with a range of values used is 20-27 which is shown in equation (3), and the "hot" fuzzy set with a range of values used is >27 which is shown in equation (4).

$$\mu \ cold(x) = \{1 \ (22.5-x)/(22.5-18) \ 0 \quad x \leq 18 \ 18 \leq x \leq 22.5 \quad x \geq 22.5 \tag{2}$$

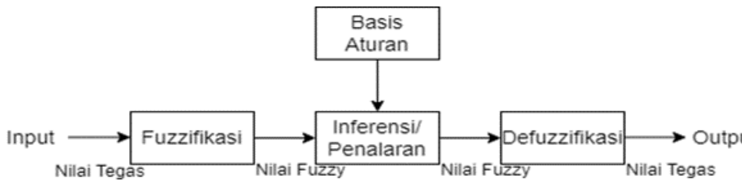


Figure 1. Fuzzy Logic Concept

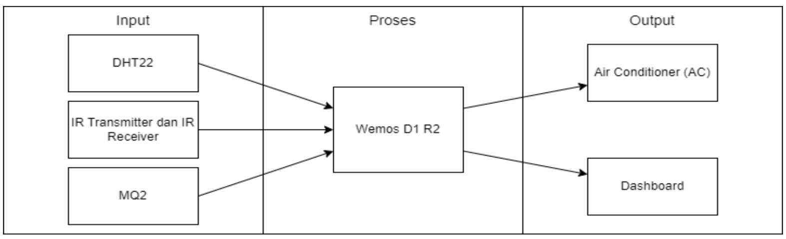


Figure 2. System Diagram Block

$$\mu \ normal(x) = \{0 \ (x-18)/(22.5-18) \ (27-x)/(27-22.5) \ x \leq 18 \ atau \ x \geq 27 \quad 18 \leq x \leq 22.5 \quad 22.5 \leq x \leq 27 \tag{3}$$

$$\mu \ hot(x) = \{0 \ x \leq 22.5 \quad (x-22.5)/(27-22.5) \quad 22.5 \leq x \leq 27 \ 1 \quad x \geq 27 \tag{4}$$

In the server room test data, the value x=22 was taken. This value illustrates that the x value is between the "cold" set and the "normal" set, while the x value is not included in the "hot" set. So the value of x can be calculated using equations 2 and 3, as follows:

$$\mu \ cold(x) = \{1 \quad (22.5-22)/(22.5-18) \quad 0 \quad 22 \leq 18 \ 18 \leq 22 \leq 22.5 \quad 22 \geq 22.5$$

$= (22.5 – 22) / (22.5 – 18)$

$= 0.11111111111$

μ normal (x) = $\{0 \quad (22 - 18)/(22.5 - 18) \quad (27 - 22)/(27 - 22.5) \quad 22 \leq 18 \; atau \; 22 \geq 27 \quad 18 \leq 22 \leq 22.5 \quad 22.5 \leq 22 \leq 27$

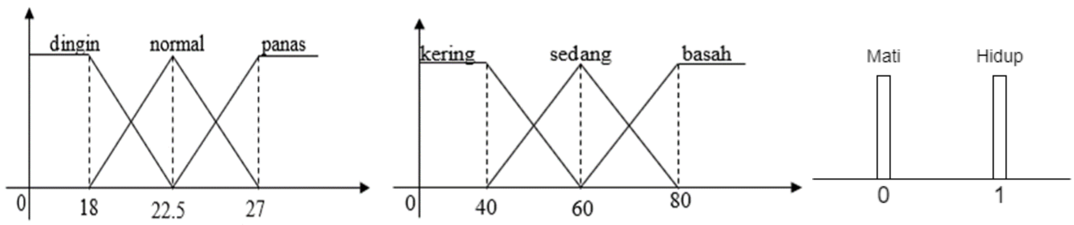
= (22 – 18) / (22.5 – 18)
= 0.88888888889

The membership function of the humidity variable is used in fuzzy logic to determine the extent to which a value "x" is included in the "dry" fuzzy set with a range of values used, namely 0-40 as shown in equation (5), for a "medium" fuzzy set with a range of values used is 40-80 as shown in equation (6), and the "wet" fuzzy set with a range of values used is >80 as shown in equation (7).

μ dry (x) = $\{1 \quad (60 - x)/(60 - 40) \quad 0 \quad x \leq 40 \quad 40 \leq x \leq 60 \quad x \geq 60$ (5)

μ medium (x) = $\{0 \; (x - 40)/(60 - 40) \; (80 - x)/(80 - 60) \quad x \leq 40 \; atau \; x \geq 80 \; 40 \leq x \leq 60 \quad 60 \leq x \leq 80$ (6)

μ wet (x) = $\{0 \quad x \leq 60 \; (x - 60)/(80 - 60) \quad 60 \leq x \leq 80 \; 1 \quad x \geq 80$ (7)



(a) Temperature Set **(b) Humidity Set** **(c) Output Set**

Figure 3. Fuzzy Membership Degrees

In the server room test data, the value x=71.5 was taken. This value illustrates that the x value is between the "medium" set and the "wet" set, while the x value is not included in the "dry" set. So the value of x can be calculated using equations 6 and 7, as follows:

μ medium (x) = $\{0 \; (x - 40)/(60 - 40) \; \frac{80-71.5}{80-60} x \leq 40 \; atau \; x \geq 80 \; 40 \leq x \leq 60 \; 60 \leq 71.5 \leq 80$

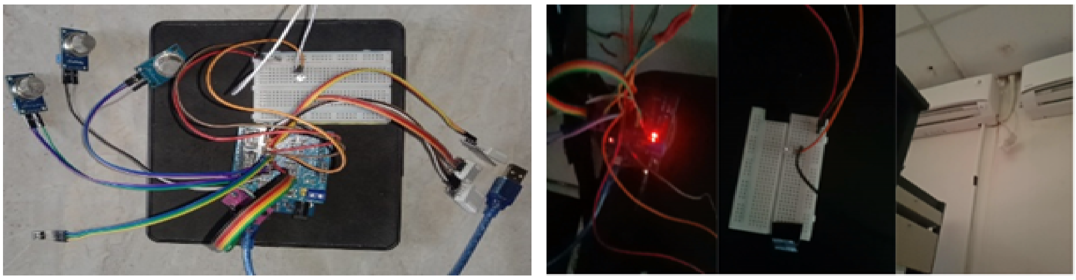
= (80 – 71.5) / (80-60)
= 0.425

μ wet (x) = $\{0 x \leq 60 \; (71.5 - 60)/(80 - 60) \quad 60 \leq 71.5 \leq 80 \; 1 \quad x \geq 80$
= (71.5 – 60) / (80-60)
= 0.575

Then, there is a fuzzy membership degree for the output indicating "AC On" and "AC Off," as seen in Figure 3(c). The degree of fuzzy membership is expressed in the value range 0 to 1, where the value 0 indicates that the output value is not included in the fuzzy set, and the value 1 indicates that the output value is completely included in the fuzzy set. The fuzzy system can provide better decisions because this system is able to overcome the complexity of various combinations of different temperature and humidity values in the server room. By utilizing fuzzy membership degrees, the system can make more adaptive and intelligent decisions in managing the AC, based on input data from temperature and humidity sensors.

1. 2.2 Inferensi/Penalaran

This stage involves rules that are determined based on the conditions in the server room. Thus, there are 9 fuzzy rules created with the IF-THEN function which are shown in Table 1. For example: IF temperature is cold AND humidity is dry THEN AC is on. In this stage, we use the MIN implication function to get the α-predicate value for each rule (α1, α2, α3,...αn). Then, this α-predicate value is used to calculate the output of crisp inference results from each rule (z1, z2, z3,...zn) shown in equation 8, where α is the minimum value of the fuzzy set A and fuzzy set B with the ith rule, μAi(x) is the degree of membership of x of fuzzy set A in the ith rule, and μBi(x) is the degree of membership of x of fuzzy set B in the ith rule. The minimum operation will select the smallest value from the existing membership levels. Minimum operations at the inference stage are used to maintain conservativeness in fuzzy reasoning. By choosing the smallest value, it can be assumed that lower membership levels reflect greater levels of uncertainty or lack of information. After carrying out minimum operations on the fuzzy set of input variables related to the inference rules, the next step is to combine the results.



(a) System Network **(b) Implementation in the Server Room**

Figure 4. Wemos D1 R2 Circuit and Implementation

(a)Sensor DHT22 **(b)Sensor MQ2** **(c)Sensor *Infrared***

Figure 5. Sensor Networks

There are other rules for carrying out the defuzzification process to produce crisp values as output from the fuzzy system.

$$\alpha_i = \mu_{Ai}(x) \cap \mu_{Bi}(x) = \min(\mu_{Ai}(x), \mu_{Bi}(x) \quad (8)$$

The example from equation 8, which uses the values from the previous calculation, where μ_{Ai} (22) gets a value of 0.88888888889 and μ_{Bi}(71.5) gets a value of 0.575, then the minimum value is as follows:

$$\alpha_i = \mu_{Ai}(22) \cap \mu_{Bi}(71.5) = \min(\mu_{Ai}(0.88888888889), \mu_{Bi}(0.575) = 0.575$$

2.3 Defuzzification

In the defuzzification process, the fuzzy output boundaries used are determined based on the membership function graph. At this stage, the Weight Average method is used by calculating the weighted average of the fuzzy set membership levels at each crisp value to determine the AC condition shown in equation 9, where α_i is the *i*-th α-predicate and Z_i is the *i*-th consequent.

$$WA = \frac{\sum_{i=1}^{N} aiZi}{\sum_{i=1}^{N} ai} \quad (9)$$

Example from equation 9, which uses values from previous calculations. At this stage, using the values obtained from the inference results and equation 8, the defuzzification results are obtained, as follows:

$$WA = \frac{0*1+0.11111111111*0+0.11111111111*0+0*1+0.425*1+0.575*1+0*1+0*1+0*1}{0+0.11111111111+0.11111111111+0+0.425+0.575+0+0+0} = 0.81818181818\ (0.82)$$

3. Result and Discussion

In this research, there are several design and testing results, including testing on Wemos D1 R2 which is shown in Figure 4(a, b). This design and testing is carried out in the server room, where this testing covers all tests on the system. Then, design and test the DHT22 sensor, where this test uses three DHT22 sensors shown in Figure 5(a), then the average value will be calculated from the three sensors. This is used to configure the three sensors so that the resulting values.

Table 1. Fuzzy rules

Rule	*Input*		*Output*
s	**Temperature**	**Humidity**	**AC**
R1	Cold	Dry	On
R2	Cold	Medium	Off
R3	Cold	Wet	Off
R4	Normal	Dry	On
R5	Normal	Medium	On
R6	Normal	Wet	On
R7	Hot	Dry	On
R8	Hot	Medium	On
R9	Hot	Wet	On

Table 2. DHT22 Sensor Test Results for Temperature

NO	**DHT22**			**Δ□**		
	∑	**Δ**	**α**	$\sum^2$	Δ^2	α^2
1	21.8	23.2	25.4	475.24	538.24	645.16
2	21.9	23.3	25.2	479.61	542.89	635.04
3	21.9	23.2	25.4	479.61	538.24	645.16
4	21.9	23.2	25.5	479.61	538.24	650.25
5	21.8	23.2	25.5	475.24	538.24	650.25
6	21.8	23.2	25.4	475.24	538.24	645.16
7	21.8	23.2	25.5	475.24	538.24	650.25
8	21.8	23.2	25.4	475.24	538.24	645.16
9	21.8	23.2	25.5	475.24	538.24	650.25
10	21.7	23.2	25.7	470.89	538.24	660.49
11	21.4	22.7	24.5	457.96	515.29	600.25
12	21.4	22.7	24.4	457.96	515.29	595.36
13	21.4	22.7	24.5	457.96	515.29	600.25
14	21.4	22.8	24.5	457.96	519.84	600.25
15	21.3	22.8	24.3	453.69	519.84	590.49
Σ	345.8	376.7	325.1	7046.69	7972.6	9463.77
	Δ□			0.22189658681016253	0.22469732728420838	0.5056349144063004

Tabl3 3. DHT22 Sensor Test Results for Humidity

NO	DHT22			Δ□		
	∑	Δ	α	$\sum^2$	Δ^2	α^2
1	72.5	70.2	57.3	5256.25	4928.04	3283.29
2	72.6	70.3	57.8	5270.76	4942.09	3340.84
3	72.4	70.2	57.6	5241.76	4928.04	3317.76
4	72.4	70.5	57	5241.76	4970.25	3249
5	72.1	70.1	56.8	5198.41	4914.01	3226.24
6	72	69.7	56.9	5184	4858.09	3237.61
7	71.8	69.5	56.5	5155.24	4830.25	3192.25
8	71.8	69.5	56.5	5155.24	4830.25	3192.25
9	72.1	69.8	56.5	5198.41	4872.04	3192.25
10	73.7	71.2	57.7	5431.69	5069.44	3329.29
11	71.8	71	59.5	5155.24	5041	3540.25
12	72	71.2	59.5	5184	5069.44	3540.25
13	72	70.8	59.5	5184	5012.64	3540.25
14	72.1	70.7	59.3	5198.41	4998.49	3516.49
15	72.3	70.7	59.5	5227.29	4998.49	3540.25
Σ	1083.6	1055.4	867.9	78282.46	74262.56	50238.27
	Δ□			1.8504825625495638	2.2238961949043397	4.809028999194993

The more accurate in measurements. Next, designing and testing the MQ2 sensor, where this test uses three MQ2 sensors as shown in Figure 5(b). After that, design and test the IR remote control shown in Figure 5(c). In this test, it is used to determine the distance from the infrared sensor to be accepted by the AC.

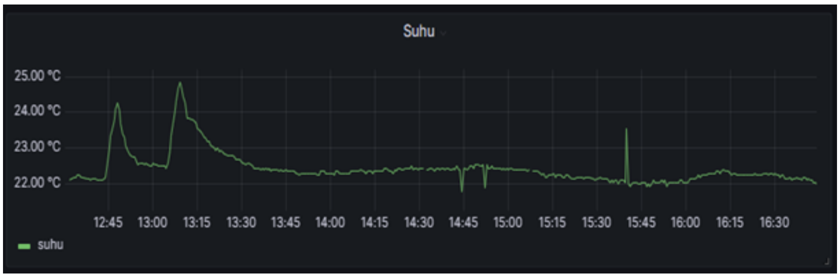


Figure 6. Graph of Temperature Measurement Results

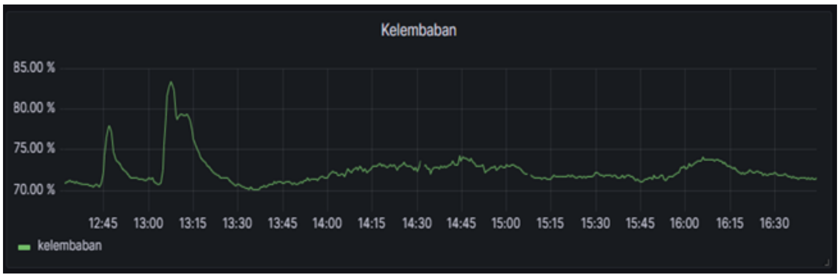


Figure 7. Humidity Measurement Results Graph

Figure 8. Graph of Smoke Rate Measurement Results

3.1 Planning and Testing Wemos D1 R2

Wemos D1 R2 testing is used to determine the overall performance of the system. The system block diagram is shown in Figure 2, where Wemos D1 R2™ functions as the main microcontroller that controls all computing in the system. The DHT22™ sensor is used to measure the temperature and humidity of the server room, while the MQ2™ sensor is used to measure smoke levels. The IR Transmitter and IR Receiver are used as controls to control the AC, and the dashboard is used to display data related to the condition of the server room. In this research, time constraints in testing systems created in the server room are a problem that needs to be considered. Unstable server room conditions cause uncertainty in measurements, and there is concern that undesirable situations may occur during testing. Therefore, the test time is adjusted when the server room is working more frequently or is active. By adjusting the test time to the period when the server room is active, it is hoped that the data obtained is more representative of daily operational conditions and provides a more accurate understanding of system performance in a more realistic environment.

3.2 Design and Testing of the DHT22 Sensor

At the DHT22 temperature sensor testing stage, there are two tests, namely testing temperature and humidity. At the DHT22 sensor temperature testing stage, measurement uncertainty is calculated. This test involves the use of three DHT22 sensors as in Figure 5(a). To calculate the uncertainty in repeated measurements from the DHT22 sensor, use equation 9, where "Δx" is the uncertainty of repeated measurements, "N" is the amount of data used, "$\sum$" is the sigma symbol used to represent the addition operation, "i" is the index used in addition, "x" is the average value of the data, namely the result of adding all data elements raised to the power of 2, and "x" is the individual data element used in calculating the standard deviation. as follows:

Table 4. MQ2 Sensor Test Results for Smoke

Smoke Testing Distance with MQ2 Module	Smoke Sensor Data						Status
	1	ppm	2	ppm	3	ppm	
<40	283	2983.382	218	2367.057	209	2281.720	Smoke
>40	178	1987.781	192	2120.527	144	1665.395	No Smoke

Table 5. Infrared Sensor Test Results for AC

Sensor Distance to AC (cm)	Description
<230	Signal Received
>230	Signal Not Received

Table 6. Fuzzy Calculation Test Results

-th Test	Testing Data		Fuzzy output based on manual calculations in excel	Fuzzy result output
	Temperature	Humidity		
1	22.5	71.35	1	1
2	22.6	71.45	1	1
3	22.55	71.3	1	1
4	22.55	71.45	1	1

-th Test	Testing Data		Fuzzy output based on manual calculations in excel	Fuzzy result output
	Temperature	Humidity		
5	22.5	71.1	1	1
6	22.5	70.85	1	1
7	22.5	70.65	1	1
8	22.5	70.65	1	1
9	22.5	70.95	1	1
10	22.45	72.45	0.98	0.98
11	22.1	71.4	0.85	0.85
12	22.1	71.6	0.85	0.85
13	22.05	71.4	0.83	0.83
14	22.05	71.4	0.83	0.83
15	22	71.5	0.82	0.82

Table 7. Fuzzy Output Calculation Results based on Fuzzy Output

-th Test	Testing Data		Expected AC output	Output test results
	Temperature	Humidity		
1	22.5	71.35	On	On
2	22.6	71.45	On	On
3	22.55	71.3	On	On
4	22.55	71.45	On	On
5	22.5	71.1	On	On
6	22.5	70.85	On	On
7	22.5	70.65	On	On
8	22.5	70.65	On	On
9	22.5	70.95	On	On
10	22.45	72.45	On	On
11	22.1	71.4	On	On
12	22.1	71.6	On	On
13	22.05	71.4	On	On
14	22.05	71.4	On	On
15	22	71.5	On	On

$$\Delta \square = \frac{1}{\sqrt{N}}\sqrt{\frac{N(\sum_i X^2)-(\sum_i x)^2}{(N-1)}} \quad (9)$$

An example of equation 9 is shown as follows. if N=15, ∑= 325.1, ∑2=7046.69 then the value of the repeated measurement uncertainty is as follows:

$$\Delta \square = \frac{1}{\sqrt{15}}\sqrt{\frac{15(7046.69)-(325.1)^2}{(15-1)}}$$

Figure 9. Controlling Dashboard Page

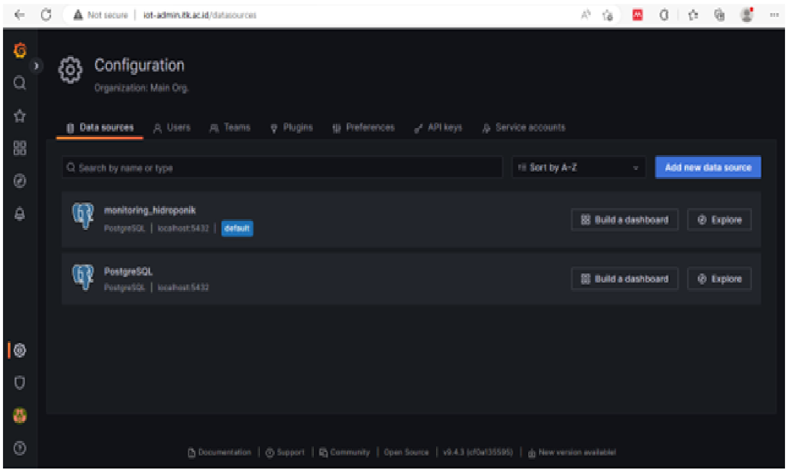


Figure 10. Data Source page

$$\Delta\square = \frac{1}{\sqrt{15}}\sqrt{\frac{105.700,35-105.690,01}{(15-1)}}$$

$$\Delta\square = \frac{1}{\sqrt{15}}\sqrt{0.73857142857}$$

$$\Delta\square = 0.22189658681016253$$

From the test results based on equation 9, the DHT22 sensor test results for temperature are shown in Table 2. The average error value of the DHT22 sensor in measuring server room temperature is obtained, where for the DHT22 sensor (∑) the uncertainty value for repeated measurements is 0.22189658681016253. The DHT22 sensor (Δ) obtained a repeated measurement uncertainty value of 0.22469732728420838. Furthermore, the DHT22 (α) sensor obtained a repeated measurement uncertainty value of 0.5056349144063004. then, a graph of the results of temperature measurements in the server room using three DHT22 sensors is shown as in Figure 6. It can be seen that the recorded temperature has increased at certain times due to several factors, improper placement of the three sensors, unstable sensor performance, and errors in DHT22 sensor reading of server room temperature. Apart from that, the graph also shows that there is a decrease in temperature at certain times. This happened because in testing the DHT22 sensor, there were several measurement results that produced NaN (Not a Number) values.

Then, at the humidity testing stage, it was carried out using equation 9. The average error value obtained from the DHT22 sensor in measuring server room humidity is shown in Table 3, where for the DHT22 sensor (∑) the uncertainty value obtained for repeated measurements was 1.8504825625495638. The DHT22 sensor (Δ) obtained a repeated measurement uncertainty value of 2.2238961949043397.

(a) Temperature Measurement **(b)Humidity Measurement**

Figure 11. Comparison of Measurements in Server Rooms

Then, the DHT22 (α) sensor obtains a repeated measurement uncertainty of 4.809028999194993. The graph shows the results of humidity measurements in the server room, where based on Figure 7, the first time the sensor reads the humidity it will experience instability in the data reading, but after some time passes, the sensor reading will stabilize again. This is because the DHT22 sensor. This is because the DHT22 sensor takes time to reach a stable condition because when it is first used the sensor will adapt to the surrounding environment.

3.3 MQ2 Sensor Design and Testing

MQ2 sensor testing was carried out to display and read real-time smoke level data in the server room. This test uses Arduino IDE software to create a simple program using three MQ2 sensors as in Figure 5(b). At the testing stage of the MQ2 sensor, it is carried out by determining whether the gas concentration is within acceptable limits. In the test results, a threshold value of 2196.8383 ppm was obtained. The threshold value is used as a threshold, where if the smoke content value is the same as the threshold value or greater then "there is smoke", but if the smoke content value obtained is smaller than the threshold value, then there is "no smoke". This test also measured the distance of the MQ2 sensor to smoke levels, where the MQ2 sensor was able to detect smoke levels with a maximum distance of 40cm to smoke as shown in Table 4. However, this test used smoke on a small scale. When measuring the smoke levels in the server room, a graph of the results of the smoke measurements is shown as in Figure 8, which shows that the smoke levels recorded on the three MQ2 sensors experienced unstable increases and decreases. This occurs due to changes in temperature, humidity, air circulation in the server room and inaccurate sensor calibration so that the sensor readings are unstable.

3.4 IR Remote Control Design and Testing

The design and testing of the IR remote control AC is carried out to operate the AC automatically in the server room using the IR transmitter as the signal transmitter and the IR receiver as the signal receiver as in Figure 5(c). In this test, Arduino IDE software is used to create a simple program, where this test is carried out to measure the maximum distance from the infrared sensor that can be received by the AC. The results obtained show that the infrared sensor is capable of sending signals with a maximum distance of 230cm to the AC as shown in Table 5. Testing of the IR remote control AC is carried out using several procedures, as follows:

1. Make a circuit Connect the IR receiver™ with Wemos D1 R2™ using jumper cables.
2. Upload the program created on Wemos D1 R2™ using Arduino ide software to get the IR code sent by the AC remote.

3. After that, create a circuit for the IR transmitter™ to send commands to the AC automatically according to the temperature and humidity conditions in the server room.

Table 8. Comparison of Assumed Power Consumption and Costs Incurred

Power (kWH)	On Time (*Non* IoT)	Consumption per Day (*Non* IoT)	On Time (IoT)	Consumption per Day (IoT)	Difference (*Non* Iot – IoT)
0.545	24	Rp. 22,229.852	12	Rp. 11,114.926	Rp. 11,114.926
			13	Rp. 12,041.170	Rp. 10,188.682
			14	Rp. 12,967.414	Rp. 9,262.4385
			15	Rp. 13,893.658	Rp. 8,336.1947
			16	Rp. 14,819.902	Rp. 7,409.9508
			17	Rp. 15,746.145	Rp. 6,483.7070
			18	Rp. 16,672.389	Rp. 5,557.4631
			19	Rp. 17,598.633	Rp. 4,631.2193
			20	Rp. 18,524.877	Rp. 3,704.9754
			21	Rp. 19,451.121	Rp. 2,778.7316

3.5 Testing Fuzzy Sugeno Results on AC

The fuzzy testing stage on AC aims to determine the accuracy and performance of the Sugeno fuzzy system regarding AC conditions. This test uses data from temperature and humidity in the server room. There are two tests, namely fuzzy logic testing and output testing for input based on fuzzy rules. In fuzzy logic testing, namely comparing the expected output related to the test result output based on the given input case. The expected output is obtained through manual calculations using Excel, while the test result output is obtained based on computational results from Wemos D1 R2. The results obtained are based on the data in table 6. The temperature and humidity data were entered manually according to the data in the test results. Based on these trials, it can be concluded that the fuzzy output value on Wemos D1 R2 is the same as the fuzzy output on Excel.

Then, testing the output against the input based on fuzzy rules, which is carried out to evaluate whether the input from all sensors can produce the appropriate AC output. Temperature input is divided into three categories, namely "cold", "normal", and "hot", while humidity input is divided into three categories, namely "dry", "normal", and "wet". The input value will be used as input in the fuzzy rules that have been created to get the expected output value. The test results output is obtained when the tool is run and will be used to evaluate system performance.

3.6 Implementation of Controlling Dashboard Design

The final testing process is testing on the dashboard which aims to display data sent by the DHT22 sensor for temperature and humidity, as well as the MQ2 sensor for smoke levels in the server room. The following are several pages from the controlling dashboard. There are several pages on the controlling dashboard, including the login page, where on this page, the user is asked to enter a username and password. However, if the user is not logged in, the user can directly access the controlling dashboard page. Then, the controlling dashboard page. On this page, users can see the temperature, humidity and gas conditions in the server room. Users can also see measurement graphs for each measured parameter. Users can also see the defuzzification results, the status of the AC condition, where if the defuzzification value is less than or equal to 0.5 then the AC is "off", but if not then the AC is "on". Users can also see the status of the gas condition, where if it passes the specified threshold, then "there is smoke" but if not, then "there is no smoke" as in figure 9. Next, the data source page in figure 10. On this page, the user You can configure to connect the database used with Grafana®. In this research, the database used is PostgreSQL®.

3.7 Comparison of the Implementation of IoT Systems to Support ISO 27001:2005 with Non-IoT Based Systems

In this section, comparisons are made by comparing the temperature and humidity conditions in the server room, namely the thermopro tool used in the server room with the system being created. Data is taken every 30 seconds with 10 data collection trials. In the comparison of temperature measurements, the results obtained show differences in temperature measurements in the server room as in Figure 11(a), where by using the DHT22 sensor, the temperature read is lower due to the placement of the sensor used with the thermopro tool being different. Then, when testing the DHT22 sensor, there were several measurement results which produced NaN (Not a Number) values. After that, a comparison of humidity measurements, where the results obtained show differences in humidity measurements in the server room, shown in Figure 11(b). The sensor used produces a higher value than the thermopro measuring instrument because the sensor used requires time to reach a stable condition.

If assumed, the implementation of this IoT system is to support ISO 27001:2005 with non-IoT based systems. Viewed from the perspective of the effectiveness of costs incurred per day, it can be calculated using equation 2, as follows:

Electric power (kWH) x Time of electricity use (hours) x Cost (Rp) (10)

Information:
- AC 1 Pk (545 watts) = 0.545 kWH
- Subsidized 450 VA Power Household Customers of IDR 415/kWh.
- Subsidized 900 VA Power Household Customers of IDR 605/kWh.
- 900 VA RTM Household Customers (Affordable Households) Rp. 1,352/kWh.
- Household customers with power 1,300-2,200 VA amounting to IDR 1,444.70/kWh.
- Household customers with a capacity of 3,500 and above are IDR 1,699.53/kWh.

Assumption:
- AC 1 PK
- 3500 VA Customer Power

The assumptions shown from the comparison of power consumption and costs incurred before and after implementing an IoT-based server room controlling system are as shown in Table 8. It can be seen that the IoT system can save power consumption and costs incurred compared to non-IoT. This is because when implementing an IoT system, the duration of electricity usage will be adjusted to the conditions in the server room.

4. Conclusion

In research on the development of an IoT-based server room controlling system using the fuzzy Sugeno method. Several conclusions were obtained based on the problem formulation that had been made, as follows:

1. This system has a level of uncertainty for each DHT22 sensor regarding temperature measurements, where for the DHT22 sensor (1) the uncertainty value for repeated measurements is 0.22%. The DHT22 sensor (2) obtained a repeated measurement uncertainty value of 0.22%. The DHT22 sensor (3) obtained a repeated measurement uncertainty value of 0.50%. Then, for the level of uncertainty for each DHT22 sensor regarding humidity measurements, for the DHT22 sensor (1) the uncertainty value for repeated measurements is 1.85%. The DHT22 sensor (2) obtained a repeated measurement uncertainty value of 2.22%. The DHT22 sensor (3) obtains a repeatable measurement uncertainty of 4.80%. The Sugeno fuzzy method was successful in determining the condition of the AC between on and off which was adjusted to the conditions in the server room. However, there is a problem where the DHT22 sensor produces temperature and humidity readings that are higher than the proper values in the server room. Then, a threshold of 2196.8383 ppm was set for the MQ2 sensor to detect smoke on a small scale.

2. In this research, analysis and implementation of the ISO:27001 security standard has been carried out in the server room of the Kalimantan Institute of Technology. By maintaining the server room temperature between 20-25oC and humidity between 40-55%, the Kalimantan Institute of Technology has succeeded in creating an optimal environment to maintain system performance. However, in testing the server room, there were differences in temperature and humidity readings between the device used and the thermopro tool used to measure the condition of the server room. This causes the need to adjust the range of temperature membership degrees between 18-27oC and humidity membership degrees of 40-80%, where later the defuzzification value will be used as an AC output setting. In this way, the difference in readings between the device and the thermopro tool can be minimized so that better accuracy is achieved.

In the future, this research can be developed more widely using other methods. Then, when testing devices in the server room, it is recommended to place sensors strategically according to the conditions in the server room by testing the system over a 24 hour period to monitor overall system performance. Apart from that, it is necessary to calibrate the sensor properly to ensure that the sensor can work properly. All work in this research can be referenced on the following Github link: https://github.com/DewiAnjani19/monitoring_server.git

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How to cite this article:

Anjani D, Fiqar T P, Abdullah R K. Use of the Information Security Index (KAMI) 4.2 as an Evaluation Method at the Paser Regency Communication, Informatics, Statistics and Coding ServiceDesign and Implementation of Server Room Controlling using the Fuzzy Sugeno Method. *Jurnal Teknologi dan Manajemen.* 2024 July; 5(2):89-103. DOI: 10.31284/j.jtm.2024.v5i2.4653