Smart Chicken Coop Ecosystem for Optimal Growth of Broiler Chickens Using Fuzzy on IoT

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Abstract— Chicken consumption is one of the high-value economic sectors. In order to harvest chickens optimally, it is necessary to maintain the temperature and humidity of the chicken coop regularly. The application of IoT to monitor the temperature and humidity of the chicken coop is significant. Therefore, an automatic temperature-humidity control system based on decisions made using the Sugeno fuzzy method is also needed. Smart chicken coop with the fuzzy algorithm on platform internet of things can be used as an alternative process temperature and humidity control automatically replace conventional method. Based on the results of the tests, this system can control temperature and humidity at 30.3°C, which is the ideal temperature for the growing time of broilers.

Keywords— Internet of Thing, Temperature Humidity Monitoring System, Fuzzy Sugeno, NodeMCU

I. Introduction

Livestock is one of the most extensive food supplies after agriculture. Livestock is an essential sector in the national economy. Currently, the development of the livestock sub-sector is in progress; one of the goals is to meet the needs of animals from livestock. The need for animal sources from milk, eggs, and meat in Indonesia is increasing. This increase occurred due to rapid population growth, improving people's purchasing power, and increasing public awareness of the importance of nutritious food [1]. One of the foodstuffs that make a significant contribution to animal protein needs is chicken meat. Chicken is one of the foodstuffs that contain high enough animal protein to meet human needs. Chicken is very popular with the community because it is easy to cook and process. In addition, chicken meat has a good taste and can be accepted by everyone, and the price is lower than other meats [2].

Trade Research and Development Association of Indonesia states that Broiler's meat consumption per capita in Indonesia (2017-2021) has increased from year to year, between 2017-2021 the Per-Capita Chicken Meat Consumption Figures reached 5.68, 5.67, 5.69, 5.68, and 5.86 kilograms/capita/year, respectively. It also impacts the demand and needs for chicken meat in the market.

Based on market demand for chicken meat, one of the exciting business activities to study in the livestock industry is broiler agribusiness or often referred to as broiler chicken. Broiler chicken farming is one of the livestock businesses with great potential to be developed because it has higher production than native chickens. Weight growth is very fast in a relatively short time. Another advantage that farmers can feel is the rapid rate of capital turnover so that the costs incurred during maintenance will quickly return. This is the main attraction for entrepreneurs and breeders in broiler farming [3].

Chicken is a warm-blooded (endothermic) animal whose body temperature is regulated by an appropriate limit. Chickens can reproduce optimally if internal and external factors are within normal limits according to their needs [4]. Broiler chickens are very susceptible to extreme changes in environmental temperature. Broiler chickens have optimal temperature and humidity to support growth [5]. The temperature and humidity requirements of broilers during the brooding period are 29°C-35°C, and the humidity is 60%-70% [6]. The care of this type of chicken has many difficulties, one of which is that the room temperature in the coop must be stable and maintained. Temperature changes can affect the growth and development of broiler chickens. Temperatures that are too high can cause a decrease in appetite in chickens so that chickens will drink more often than eat. This condition will impact reducing the weight of the chicken produced. Temperature and humidity that is too high cause heat stress in chickens [7]. Lack of ventilation also affects the temperature of the coop, which makes the coop feel hot for the chickens [8]. The characteristics when chickens experience heat stress are increased water consumption, decreased feed, painting, developing wings, anxiety that can interfere with chicken growth and lead to death.

Many factors influence the success of breeders, namely good maintenance management. One of them is the microclimate factor (temperature and humidity) that affects the coop's comfort, so its condition must be carefully considered. Type coops are "close houses" believed in providing good coop ventilation without being disturbed by climate changes outside the coop environment [9]. Improved performance is the main advantage of this system close house. Good management, maintenance, and the comfort of the coop will stimulate optimal growth of chickens, namely growing

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fast with high-efficiency levels without experiencing Slow Growth Syndrome or slowing growth disorders in chickens. There are several ways to stabilize the air humidity in the coop, one of which is by using a water pump that will be splashed on livestock that experiences an increase in effective temperature due to the high level of humidity in the coop seen from the behavior of the cattle themselves [10].

Based on these problems, the authors intend to create a control system to regulate the room temperature in the coop automatically by utilizing IoT so that it can be monitored remotely in real-time so that farmers get optimal chicken development. The temperature and humidity data in the coop will be analyzed with a fuzzy algorithm. The reason to use Fuzzy Inference Sugeno is that Fuzzy logic is very flexible, has tolerance, and has an easy-to-understand concept. Fuzzy can also model highly complex nonlinear functions and directly construct and apply expert experience without training. Fuzzy can work with conventional control techniques based on natural language [19]. The fuzzy output results are used by actuators (fans and pumps) to work so that the temperature and humidity of the coop reach a stable condition if there is an increase in air humidity temperature. It is hoped that this tool can help farmers stabilize the room temperature to get optimal growth of chickens.

II. Research Methodology

This study uses a research methodology by describing several things related to solutions in the internet of things (IoT) and the use of fuzzy methods as described in the IoT architecture as well as system concepts and flow diagrams of the system.

A. *System Concept and Workflow*

This section will discuss the concept and workflow of the smart chicken coop system. The process in the system will be explained in the system flow and system architecture as follows in Figure 1.

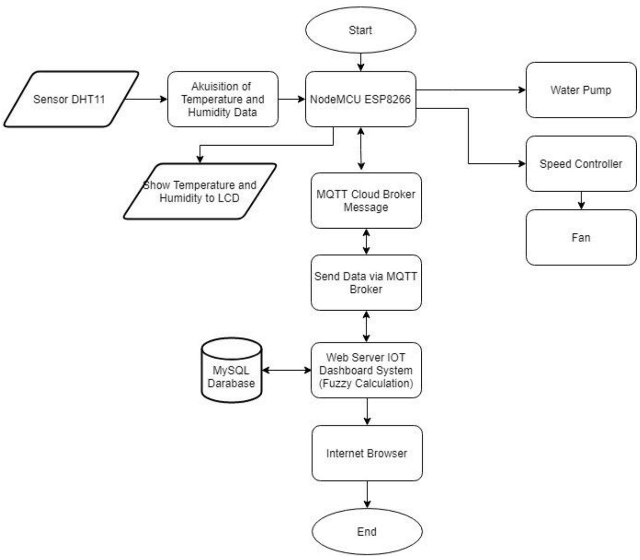

Figure 1. Architectural Design

The temperature and humidity control system in this smart chicken coop will be controlled directly by the NodeMCU Esp8266 as a microcontroller. The Sugeno fuzzy determines the output value of the fan rotation speed and water pump response.

The initial process carried out in architectural design is collecting input data from sensors. Sensor acquisition data obtained on the microcontroller will be forwarded to the server to be processed using the fuzzy method, whose output will regulate the fan and water pump. Temperature and humidity data will be duplicated in the LCD so that the temperature in the coop can still be monitored

The transmission process utilizes MQTT in the communication protocol, which is ideal for machine-to-machine and IoT communication concepts with low power and resource consumption. The processed data will be stored in the webserver database. The data taken from the server will be presented in the form of a dashboard containing data on the age of the chickens, temperature, and humidity conditions in real-time from the coop. Users can monitor the temperature conditions of the coop on the website, the system design shown in Figure 2.

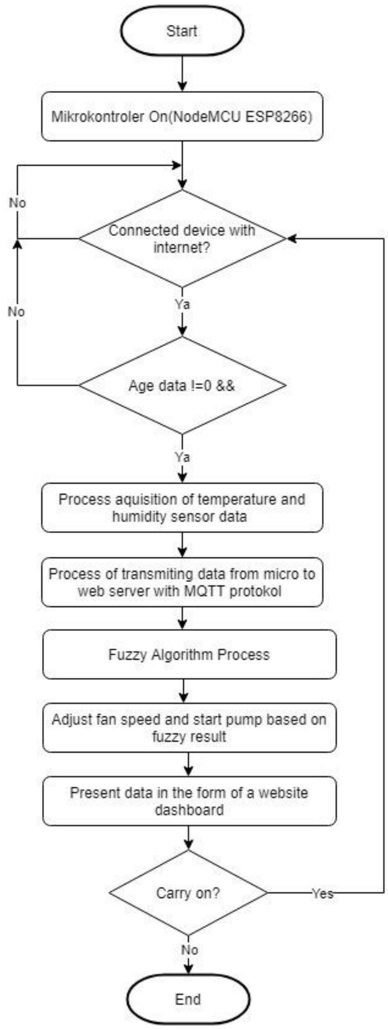

Figure 2. System Design

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B. IoT and MQTT

This section reviews the internet of things concept used in implementing smart chicken coops with MQTT as the protocol. The Internet of Things, also known as the acronym IoT, aims to expand the benefits of internet connectivity. IoT can be defined as a connection or link between physical devices with sensors and actuators to the internet, where devices are intelligently linked together, allowing for the exchange of data and information [11]. Sensors collect data from various physical conditions such as temperature and humidity, transmitting these data [12].

A device connection and data sensing are required. In addition to components, communication capabilities between systems are also needed in building IoT. The database server is used to store and analyze the results of sensing data acquisition. In this study, the Internet of Things concept will be utilized to build a temperature control system humidity using fuzzy algorithms to analyze data acquisition results from temperature and humidity sensors. In simple terms, the Internet of Things concept can be described in architecture, as shown in Figure 3.

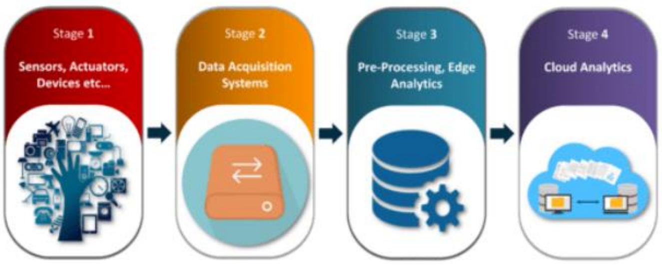

Figure 3. Architecture Internet of Things

In the first stage is a sensor/actuator, a thing in the context of the "Internet of Things," must be equipped with sensors and actuators to provide the ability to transmit, receive, and process signals. The second stage is a data acquisition system, namely data from sensors starting in an analog form which needs to be collected and converted into a digital stream for further processing. The data acquisition system performs this data aggregation and conversion function. Next, there is the edge analysis stage, i.e., once the IoT data is digitized and collected, it may require further processing before it enters the data center. This is where Edge Analytics comes in. Moreover, the last stage is cloud analytics, where data that requires more in-depth processing is forwarded to physical data centers or cloud-based systems [13][14].

This processed data is then used to do smart things for IoT purposes. On the user side, IoT services are utilized through mobile applications on their smart devices. This intuitive mobile application helps users manage and monitor their devices remotely [15].

Message Queuing Telemetry Transport (MQTT) is an-based lightweight messaging protocol open-source with a working system using the method publish/subscribe message. This protocol runs on data packets low overhead small with little power consumption. MQTT is simple, open, and easy to implement [16]. MQTT can handle thousands of clients remote with just one server; these characteristics make it ideal for use in communications Machine to Machine (M2M) and contexts Internet of Things where a small code footprint and limited network are required [17].

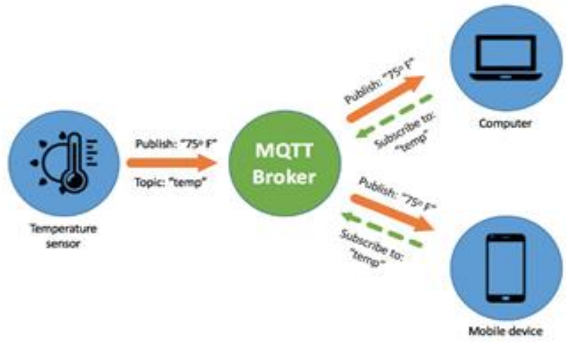

Figure 4. Illustration of MQTT work

In MQTT, the device that publishes messages is called a publisher, while the device that subscribes is called a subscriber, and the two devices are connected through a link called a broker. The message sent by the publisher will be forwarded to the subscriber through the broker. The subscriber-only needs to subscribe to the desired topic from the publisher. After that, the subscriber will get the data without making repeated requests [18]. The illustration of the MQTT workflow is shown in Figure 4.

C. Fuzzy Sugeno Method

The steps in using the fuzzy Sugeno method in this study are as follows:

Step 1: Determination of linguistic values. Value linguistically interval numeric value - the value of linguistics, the semantic can be defined by the membership function value of linguistics in this study can be seen in Table I.

TABEL I
LINGUISTIC VALUE

Variable Value	**Linguistic Value**
Age	Child, Teenage, Adults
Temperature	Cold, Normal, Heat
Humidity	Dry, Normal, Moisture
Fan Speed	Very Slow, Slow, Slightly Slow, Medium, Slightly Medium, Normal, Fairly Fast, Fast, Too Fast, Very Fast
Pump Condition	On, Off

Step 2: Fuzzification is used to change information from sensor data input to linguistic fuzzy set data.

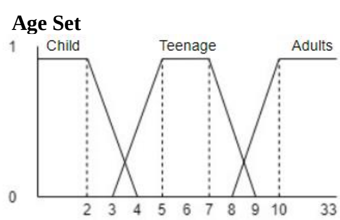

Figure 5. Age Membership Function

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Figure 5 shows that the variable has a membership function divided into three parts: children, adolescents, and adults. Each - each with the following parameters:

- Children = 1 - 4 days.
- Teenage = 3 - 9 days.
- Adults = 8 – 33 days.

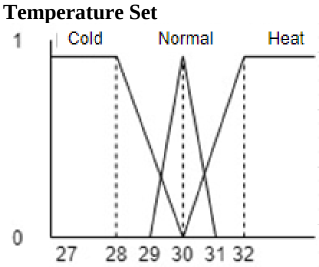

Figure 6. Temperature membership function

Figure 6 shows the variable has a membership function which is divided into three parts, namely cold, normal and hot, with the following parameters:

- Cold = 27℃ - 30℃.
- Normal = 29℃ - 31℃.
- Heat = 30℃ - 33℃.

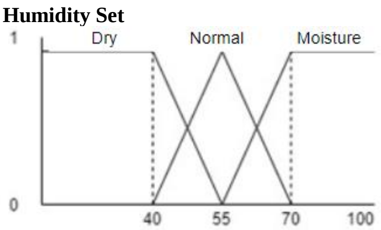

Figure 7. Humidity membership function

Figure 7 shows the variable has a membership function divided into three parts, namely dry, normal and moist. Each with the following parameters:

- Dry = 40% - 55%.
- Normal = 40% - 70%.
- Moisture = 55% - 100%

a) Fan Speed Set: The output value is constant and is divided into ten parts, namely very-slow (VS), slow (S), somewhat slow (SS), medium(M), relatively medium (SM, normal(N), reasonably fast (FF), fast (F), very-fast (VF), and too fast (TF) to control the fan speed. The membership function of the fan speed set is shown in Figure 8.

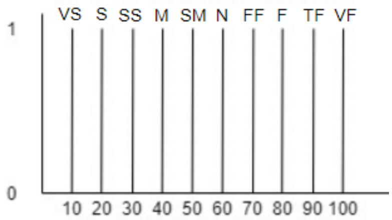

Figure 8. Fan Membership Function

b) Pump Set: The membership function is included in the output, divided into two parts: On (1) and Off(0). The relay module is used to control the condition of the pump. The membership function of the pump set is shown in Figure 9.

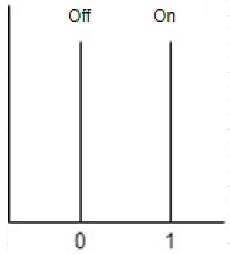

Figure 9. Pump Membership Function

The fuzzy rule base contains several fuzzy rules that map fuzzy input values to fuzzy output values. This rule is often expressed in the IF-THEN format. The base of the rules that have been made is as follows in Table II. Fuzzy inference, implication processes are performed after considering all the membership values of input temperature and humidity. The implication function uses the minimum (MIN) formula.

TABEL II
RULE FUZZY

	Input			Output	
Rule	**Age**	**Temp**	**Rh**	**Fan**	**Pump**
R1	Child	Cold	Dry	Very Slow	On
R2	Child	Cold	Normal	Very Slow	Off
R3	Child	Cold	Moisture	Slow	Off
R4	Child	Normal	Dry	Slow	On
R5	Child	Normal	Normal	Slightly Slow	Off
R6	Child	Normal	Moisture	Medium	Off
R7	Child	Heat	Dry	Slightly Medium	On
R8	Child	Heat	Normal	Normal	Off
R9	Child	Heat	Moisture	Fast	Off
R10	Teenage	Cold	Dry	Slow	On
R11	Teenage	Cold	Normal	Medium	Off
R12	Teenage	Cold	Moisture	Slightly Medium	Off
R13	Teenage	Normal	Dry	Slightly Medium	On
R14	Teenage	Normal	Normal	Normal	Off
R15	Teenage	Normal	Moisture	Fairly Fast	Off
R16	Teenage	Heat	Dry	Fairly Fast	On
R17	Teenage	Heat	Normal	Fast	Off
R18	Teenage	Heat	Moisture	Very Fast	Off
R19	Adults	Cold	Dry	Slightly Medium	On
R20	Adults	Cold	Normal	Slightly Slow	Off
R21	Adults	Cold	Moisture	Slow	Off
R22	Adults	Normal	Dry	Fast	On
R23	Adults	Normal	Normal	Fairly Fast	On
R24	Adults	Normal	Moisture	Normal	Off
R25	Adults	Heat	Dry	Too Fast	On
R26	Adults	Heat	Normal	Too Fast	On
R27	Adults	Heat	Moisture	Very Fast	Off

Step 3: Defuzzification, after knowing all the implication values of each rule for each value of and z. then proceed to the defuzzification stage. At this stage, calculations will be

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carried out using the average method with the following Equation (1).

$$z = \frac{\sum a_i z_i}{\sum a_i} \quad (1)$$

III. Result and Discussion

A. Sugeno Fuzzy Calculation Analysis

In This analysis, the Sugeno fuzzy calculation is implemented to find the fan and pump speed output in adjusting the actuator in the enclosure. The following is a breakdown of the Sugeno fuzzy calculation flow with the assumption that the data obtained by the DHT11 sensor is 15 days old, temperature 30°C, and humidity 70%.

The calculation of the three membership functions of the age set is shown in equation 2.

- For the value of Child with the following conditions:

$$\mu|\text{Child}| = \begin{cases} 1; & x \le 2 \\ \frac{4-x}{4-2}; & 2 < x \le 4 \\ 0; & x > 4 \end{cases}$$

- For the value of teenage with the following conditions:

$$\mu|\text{Teenage}| = \begin{cases} 0; & x \le 3 \; or > 9 \\ \frac{x-3}{4-3}; & 3 < x \le 4 \\ \frac{9-x}{9-4}; & 4 < x \le 9 \end{cases} \quad (2)$$

- For Adults with conditions:

$$\mu|\text{Adults}| = \begin{cases} 0; & x \le 8 \\ \frac{x-8}{9-8}; & 8 < x \le 8 \\ 1; & x > 8 \end{cases}$$

The chicken is known that the age of 23 days, the obtained results of fuzzification age as follows:
μChild[15] = 0 ; μTeenage[15] = 0 ; μAdults[15] = 1

When using equation 3, the computation of the temperature set's three-membership function is performed.

- For the value of Cold with the following conditions :

$$\mu|\text{Cold}| = \begin{cases} 1; & x \le 28 \\ \frac{30-x}{30-28}; & 28 < x \le 30 \\ 0; & x > 30 \end{cases}$$

- For the Normal value with the following conditions:

$$\mu|\text{Normal}| = \begin{cases} 0; & x \le 29 \; atau \ge 31 \\ \frac{x-29}{30-29}; & 29 < x \le 30 \\ \frac{31-x}{31-30}; & 30 < x < 31 \end{cases} \quad (3)$$

- For the value of Heat with the following conditions :

$$\mu|\text{Heat}| = \begin{cases} 0; & x \le 30 \\ \frac{x-30}{31-30}; & 30 < x \le 31 \\ 1; & x > 31 \end{cases}$$

It is known that the temperature is 22 °C, the obtained results of fuzzification temperature as follows:
μCold[30] = 0 ; μNormal[30] = 1 ; μHeat[30] = 0

As shown in Equation 4, the calculation of humidity's third set of membership functions is performed.

- For the value of Dry with the following conditions :

$$\mu|\text{Dry}| = \begin{cases} 1; & x \le 40 \\ \frac{55-x}{55-40}; & 40 < x \le 55 \\ 0; & x > 55 \end{cases}$$

- For Normal value with the following conditions using Equation (4)

$$\mu|\overline{\text{Normal}}| = \begin{cases} 0; & x \le 40 \; atau \; x \ge 70 \\ \frac{x-40}{55-40}; & 40 < x \le 55 \\ \frac{70-x}{70-55}; & 55 < x \le 70 \end{cases} \quad (4)$$

- For the value of Moisture with the conditions

$$\mu|\text{Moisture}| = \begin{cases} 0; & x \le 55 \\ \frac{x-55}{70-55}; & 55 < x \le 70 \\ 1; & x > 70 \end{cases}$$

It is known that the temperature is 70%, then the fuzzification results are obtained as follows:
μDry[70] = 0 ; μNormal[70] = 0 ; μMoisture[70] = 1

The implication function uses the minimum calculation (MIN) by taking the smallest value from the fuzzification of temperature and humidity, as in equation 5.

$$\alpha i = \mu \, A1(X) \cap \mu \, B1(X) = MIN\{\mu \, A1(X), \mu \, B1(X)\} \quad (5)$$

In determining this status output using the Zero Order Fuzzy Sugeno Method as in equation 6.

IF(X1 is A1).(X2 is A2).(X3 is A3).(X4 is A4)…
(Xn is An) THEN z = k (6)

Where *Xn* variable is any variable input, and *An* variable is the set of membership.

The following is the rule base for determining lamp and fan output:

- [R1] IF Child Age AND Cold Temperature AND Dry Humidity THEN Very Slow Fan, Pump Runs = MIN(0; 0; 0) = 0

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- [R2] IF Child Age AND Cold Temperature AND Humidity Normal THEN Fan Very Slow, Pump Off = MIN(0; 0; 0) = 0
- [R3] IF Age Child AND Cold Temperature AND Humidity Moisture THEN Fan Slow, Pump Off = MIN(0; 0; 1) = 0
- [R4] IF Age Child AND Normal Temperature And Humidity Dry THEN Slow Fans, Pumps Life = MIN(0; 1; 0) = 0
- [R5] IF Child Age AND Normal Temperature AND Humidity Normal THEN Fan Slightly Slow, Pump Off = MIN(0; 1; 0) = 0
- [R6] IF Child Age AND Normal Temperature AND Humidity THEN Medium Fan, Pump Off = MIN(0; 1; 1) = 0
- [R7] IF IF Child Age AND Hot Temperature AND Dry Humidity THEN Slightly Medium Fan, Pump On = MIN(0; 0; 0) = 0
- [R8] IF Child Age AND Hot Temperature AND Normal Humidity THEN Normal Fan, Pump Off = MIN(0; 0; 0) = 0
- [R9] IF Child Age AND Hot Temperature AND Humid Humidity THEN Fast Fan, Pump Off = MIN(0; 0; 1) = 0
- [R10] IF Teenage Age AND Cold Temperature AND Dry Humidity THEN Slow Fan, Pump On = MIN(0; 0; 0) = 0
- [R11] IF Teenage Age AND Temperature Cold AND Normal Humidity THEN Medium Fan, Pump Off = MIN(0; 0; 0) = 0
- [R12] IF Teenage Age AND Cold Temperature AND Humidity THEN Fan Slightly Medium, Pump Off = MIN(0; 0; 1) = 0
- [R13] IF Teenage Age AND Normal Temperature AND Dry Humidity THEN Fan Slightly Medium, Pump On = MIN(0; 1; 0) = 0
- [R14] IF Teen Age AND Normal Temperature AND Normal Humidity THEN Fan Normal, Pump Off = MIN(0; 1; 0) = 0
- [R15] IF Teenage Age AND Normal Temperature AND Humidity THEN Fairly Fast Fan, Pump Off = MIN(0; 1; 1) = 0
- [R16] IF Teenage Age AND Hot Temperature AND Dry Humidity THEN Fairly Fast Fan, Pump On = MIN(0; 0; 0) = 0
- [R17] IF Teenage Age AND Hot Temperature AND Normal Humidity THEN Fast Fan, Pump Turns Off = MIN(0; 0; 0) = 0
- [R18] IF Teenage Age AND Hot Temperature AND Humid Humidity THEN Very Fast Fan, Pump Off = MIN(0; 0; 1) = 0
- [R19] IF Adult Age AND Cold Temperature AND Dry Humidity THEN Fan Slightly Medium, Pump On = MIN(1; 0; 0) = 0
- [R20] IF Adult Age AND Temperature Cold AND Normal Humidity THEN Fan Slightly Slow , Pump Off = MIN(1; 0; 0) = 0
- [R21] IF Adult Age AND Cold Temperature AND Humidity THEN Slow Fan, Pump Off = MIN(1; 0; 1) = 0
- [R22] IF Adult Age AND Normal Temperature AND Dry Humidity THEN Fast Fan, Pump On = MIN(1; 1; 0) = 0
- [R23] IF Adult Age AND Normal Temperature AND Normal Humidity THEN Fairly Fast Fan, Pump On = MIN(1; 1; 0) = 0
- [R24] IF Adult Age AND Temperature Normal AND Humidity Moisture THEN Normal Fan, Pump Off = MIN(1; 1; 1) = 0
- [R25] IF Adult Age AND Hot Temperature AND Dry Humidity THEN Fan Too Fast, Pump On = MIN(1; 0; 0) = 0
- [R26] IF Adult Age AND Hot Temperature AND Normal Humidity THEN Fan Too Fast, Pump On = MIN(1; 0; 0) = 0
- [R27] IF Age Of Adulthood AND Hot Temperature AND Humidity THEN Fan Very Fast, Pump Off = MIN(1; 0; 1) = 0

Deffuzification Process aims to produce the value of crips using the weighted average formula as follows:

- Fan output defuzzification $Z_k = 60$.
- Pump output defuzzification $Z_k = 0$.

The manual calculations using the Fuzzy Sugeno Method with input temperature of 30°C, the humidity of 70%, and age of 15 days produce a fan output value of 60% and a pump output value of 0. This output value will regulate the condition of the actuator logic in the control system.

B. *Prototype Implementation*

The prototype used for the temperature and humidity control simulation is a mini chicken coop of 100x80x60cm made of plywood. The model is made as closely as possible to the original enclosure scheme without changing its primary function. The results of the coop prototype are shown in Figure 10 and 11.

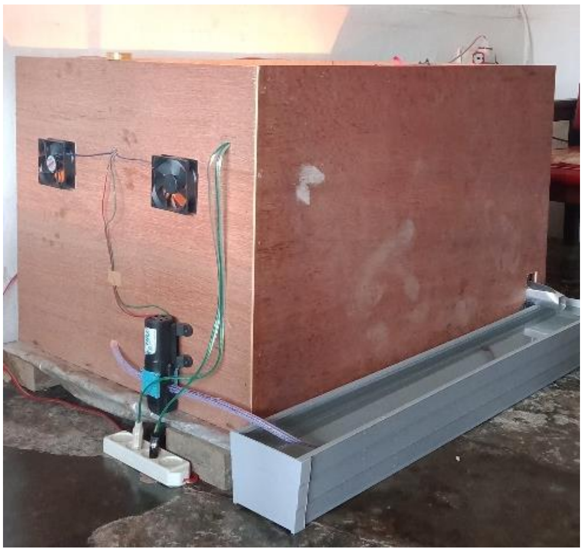

Figure 10. The prototype looks outside

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Figure 11. The prototype looks inside

C. *Dashboard and Monitoring of the Smart Chicken*

In this analysis, the author makes a dashboard and website-based monitoring system. This system is directly connected to the prototype coop in the MQTT protocol. The dashboard system consists of 4 pages. The dashboard page in Figure 12 contains some information on temperature, humidity, fan speed, and the pump in the enclosure; the data is displayed in real-time conditions. At the bottom position, there is a real-time chart of temperature and humidity to find out changes in data in particular time intervals.

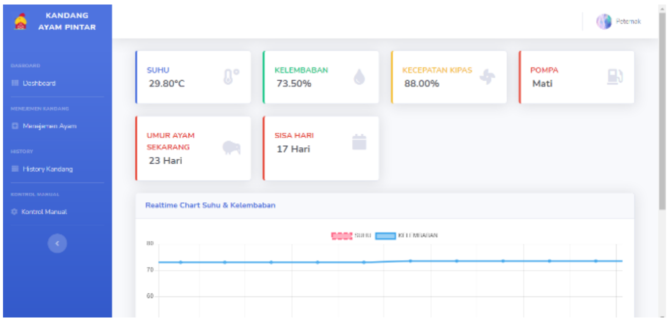

Figure 12. Home Page

The second page in Figure 13 is chicken data management. In the chicken data management menu, there is an input form in selecting a coop and inputting the age of the chicken. The data obtained from this input will start controlling the humidity temperature of the chicken coop. When there are still chickens whose temperature and humidity are being controlled, the form input will be disabled.

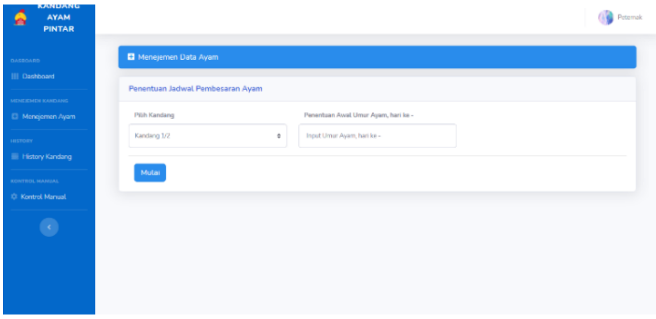

Figure 13. Chicken Data Management

Figure 14 shows the history menu. The History menu contains the history of chickens that have been controlled for temperature and humidity into the system.

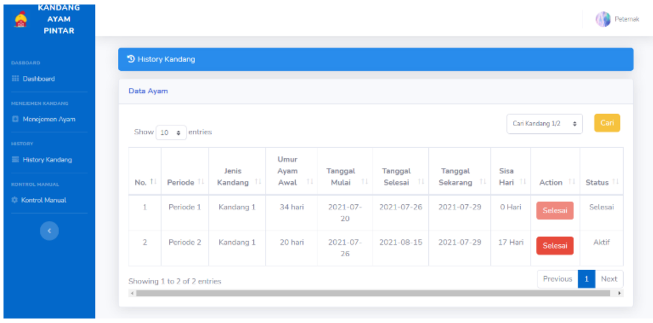

Figure 14. History Page

The last page is the manual control menu, an additional menu if there is an urgent situation that makes the user have to control the coop manually. The user can set the fan speed and pump conditions in this menu, as shown in Figure 15.

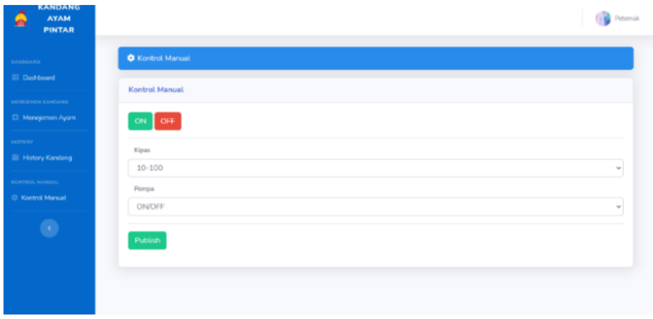

Figure 15. Manual Control Page

After the overall system is completed, an evaluation is carried out to determine whether running as expected. The evaluation orientation refers to the actuator conditions and the temperature conditions found in the coop. The assessment is carried out by paying attention to the time to determine the initial temperature shift to the ideal temperature at a specific time after the tool is turned on. The test results are stated in Table III.

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TABEL III
SYSTEM TEST RESULT

Time	Fan Speed (%)	Water Pump	DHT 11	
			Temperature (°C)	Rh (%)
1 pm	80	OFF	30.7	71.5
2 pm	80	OFF	30.45	70
3 pm	80	OFF	30.4	70.5
4 pm	80	OFF	30.2	70.5
5 pm	80	OFF	30.2	70.5
6 pm	80	OFF	30.1	70

Based on the test result in table 3, the system can control the temperature at 30.3°C and humidity at 70.5%. That value is the ideal condition for the growing time of broilers.

IV. CONCLUSION

A smart chicken coop with the fuzzy algorithm on the internet of things platform can be used as an alternative process to replace the conventional method. From the test results, this system can control temperature and humidity automatically. The integrated fuzzy algorithm in smart chicken coops with age data, temperature, and humidity as parameters can provide output values as a reference for the logic response of the actuator to make the coop conditions at the ideal temperature. The website-based dashboard and monitoring system functions as a supporter in presenting real-time data on the chicken coop, managing chicken data management, and providing features to control the condition of the chicken coop manually.

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