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Chicken Egg Hatching Optimization with Automatic Control Using Fuzzy Logic

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Abstract

Egg hatching is an important process in the livestock industry to produce quality poultry seedlings. In the hatching process environmental conditions such as temperature and humidity must be carefully regulated to ensure optimal hatching. In an effort to improve the efficiency and accuracy of hatching, this research introduces an egg hatching machine tool that adopts a fuzzy logic approach. The developed machine tool is equipped with temperature and humidity sensors that measure the environmental conditions inside the egg incubator in real-time. The data obtained from the sensors are used as inputs for a fuzzy logic-based control system that regulates the temperature and humidity of the incubator. The hatching machine is built keeping in mind the ideal conditions between 35° - 40° with 70% - 80% humidity. Fuzzy logic allows the system to handle uncertainty and ambiguity in temperature and humidity settings. Based on the fuzzy rules set, the system can adaptively adjust the environmental conditions to achieve optimal conditions for hatching *eggs*.

Keywords: Automatic Control, Chicken Egg Hatching, Fuzzy Logic, Humidity, Temperature.

INTRODUCTION

In an era of ever-evolving technology, modern agriculture is under the spotlight to bring innovative solutions to improve efficiency and productivity. One of the fields in the agricultural industry is livestock rearing, especially in breeding and hatching chicken eggs. The high public demand for chicken meat makes the breeding process very important(Rahman et al. 2020). Success in hatching chicken eggs has a significant impact on meat production and a healthy chicken population. In an effort to improve this process, automatic control technology has emerged as a promising solution, and Fuzzy Logic is an attractive method to optimize this control.

Hatching chicken eggs is an important stage in the chicken production chain, which involves the process of embryonic development inside the egg until it hatches. Hatching can be done naturally or artificially. Natural hatching involves the use of broodstock or other birds to hatch eggs(Hidayat and Risna 2022). One broodstock can often hatch up to four eggs in a single brooding period, but this isn't thought to be productive enough to meet consumer demands. Some of the problems that arise involve the limited number of broodstock owned by farmers, cannibalism in some poultry species that can be detrimental to productivity, and limited costs and land for farmers(Rahman et al. 2020). Natural hatching takes 21–22 days for chicken eggs, with a capacity that can be incubated by one poultry mother for about 10–12 eggs. The success rate of egg incubation using this traditional method only reaches about 50–60% (Islamiyah and Arifin 2023). The extended duration and comparatively low rate of success lead to a decrease in productivity. However, this kind of incubation cannot support a global population increase or the demand for chickens (Alawad, Eiman, and Ate 2021).

To avoid the disadvantages that can arise from natural hatching, artificial hatching has been introduced. With this method, one can simulate the conditions required for the hen in order to increase egg production and provide optimal conditions for the hatching process. The pioneers in the development of artificial incubation procedures were the Chinese and Egyptians (Alawad et al. 2021). The incubation process is a step to keep the fertilized eggs warm, allowing the embryo to develop optimally until it becomes a chick (Sobejana and Bacalso 2021). Forced-air incubators and still-air incubators are the two varieties of artificial incubators. The still-air incubator doesn't have a fan; the forced-air incubator has one that moves the air around the incubator chamber. Thus, compared to still-air incubators, forced-air incubators are better at maintaining temperature, humidity, and oxygen levels. For this reason, forced air flow type artificial incubators are used in nearly all recent models (Alawad et al. 2021).

An incubator or egg incubator must provide a consistent environment for the eggs to hatch. Hatchers are generally crates or cabinets with construction designed to allow heat to escape. The temperature inside the hatching machine can be adjusted according to the degree of heat required during the hatching period which ranges from 35.30°C - 40.50°C (Jufril et al. 2015). The microcontroller and IoT-based egg incubator in the egg incubator will keep the eggs warm on all sides by rotating them continuously at specific periods, allowing the embryos to develop inside and hatch without requiring the presence of the parents or the involvement of humans or farmers. It will include all necessary hatching conditions, such as temperature, humidity, air movement, and regularity of egg rotation (Izadeen and Kocher 2022).

In principle, controlling factors such as temperature, humidity, ventilation and egg turning are important aspects of hatching. Unsatisfactory hatching results are largely due to the lack of proper temperature and/or humidity control. Improper control, such as too high or too low temperature or humidity over a long period of time, can inhibit normal embryo growth (Sobejana and Bacalso 2021). Hatching egg storage should be done at temperatures equal to or higher than 37°C as embryo development will not occur at temperatures below 37°C. The ideal temperature for embryo growth is between 37°C and 39°C (Hartono, Fathuddin, and Izzuddin 2017). If the temperature during the incubation process is too high or too low, problems such as embryo death at an early stage, lack of chick development, defects, premature hatching, and others may arise. Conversely, embryos can stick to the shell if the humidity level is not maintained properly, which can lead to pre-flattening embryo death, early chick mortality, and other problems (Dutta and Anjum 2021). In general, temperatures higher or lower than 37°C can lead to incomplete embryo development and potentially hatching defective chicks (Anugerah and Stefanie 2023).

The quality of the hatching process has a significant impact on embryo development, young chick survival, and overall farm productivity. With the integration of automated controls, farmers can monitor and optimize various environmental parameters that affect hatching eggs, such as temperature, humidity, and ventilation. The application of Fuzzy Logic as an intelligent control tool offers the ability to handle uncertainty and complexity in such systems.

Boolean logic, which only has two tight sets 0 and 1 is improved upon by fuzzy logic. Rather, membership degrees in the range of 0 to 1 are introduced by fuzzy logic. The primary component of fuzzy logic reasoning is membership value, membership degree, or membership function (Bale, Djahi, and Pollo 2022). Fuzzy membership degrees are used to identify which elements are present in a significant set (Maulana, Fathurrohman, and Wibisono 2023). The fuzzy membership set is created objectively to conclusively evaluate fuzzy input and output variables, facilitating more straightforward decision-making, the fuzzy logic technique can be expanded into a more flexible programming model (Hidayat et al. 2021). A useful technique for mapping input space into output space that produces continuous values is fuzzy logic (Djara, Widiastuti, and Sihotang 2019). By utilizing the concept of fuzzy sets, fuzzy logic rules can describe human knowledge and convert it into system control. In this research on hatching chicken eggs, humidity and temperature do not always have definite values, but can be described in terms of fuzzy sets such as "high", "medium", and "low". Fuzzy logic makes it possible to devise control rules that take these variations into account, thereby maximizing the chances of egg hatching success and improving hatchability quality.

The optimal alignment of temperature and humidity during the egg hatching process is a very important aspect, as small differences in these parameters can have a significant impact on the final outcome of the hatching process. With the application of Fuzzy Logic, a control system that is responsive and adaptive to changing environmental conditions can be developed. For example, when the temperature increases beyond the desired limit, the automated system will take action by automatically setting the lights on and off. This implementation is expected to increase the survival rate of embryos and produce healthier chickens.

Egg incubator research conducted by (Kyeremeh and Peprah 2017) uses a DHT22 sensor to monitor temperature and humidity based on an Arduino microcontroller. Arduino can be used to control heating, egg rotation, and fans. Arduino will display temperature and humidity data on the LCD screen. If the sensor detects a temperature below 37.5°C, the Arduino will activate the lamp to increase the temperature and turn off the lamp to reduce the temperature until it matches the predetermined reference value.

Research (Sadi 2015) uses Zelio SR2 B121 BD programmable logic control to create a prototype room temperature control system. PLC runs the control process and the output is displayed on the LCD. The room temperature can be measured by LM35 module. The number of fans and room heating temperature affect the temperature of this prototype. All fans are turned on when the room temperature reaches 32°C. Fans four, three, and one are turned off when the room temperature reaches 29°C to 27°C. In addition, the program in this control system allows delegation or representation. The temperature will not change if one of the fans is broken or one of the switches is turned off.

The study conducted (Okpagu and Nwosu 2016) used a futuristic strategy and temperature suppression in a smart egg incubator system based on a PID controller. The strategy utilized electric light bulbs as heat source and measured the temperature with LM35 temperature sensors. Water and fan controllers are also used to maintain ideal humidity and ventilation. A DC motor rotates an iron rod under the eggs automatically to ensure that the entire egg is exposed to the heat of the lamp. The AT89C52 microcontroller serves to control these parts.

(Shafiudin and Kholis 2018) made a PID-based temperature monitoring and control system that uses an Arduino Uno microcontroller. The DHT11 temperature sensor measures the incubator temperature, and the PID controller uses the sensor value to change the incubator temperature. The research shows that the PID-based temperature monitoring and control system can maintain the incubator temperature consistently with an accuracy of ±0.5°C and can increase the egg hatching success rate to 85%. The system also displays real-time temperature data on the LCD screen and allows users to set their desired temperature.

(Alawad et al. 2021) proposed the design and implementation of an automatic egg incubator that can control temperature and humidity using Arduino IDE along with a DHT11 sensor. The Arduino Nano measures the temperature and humidity of the incubator and shows the results on a 16x2 LCD screen. This incubator also has a buzzer that will inform you if the condition of the eggs inside exceeds the standard. In addition, there is an electric lock on this incubator to prevent the door from opening accidentally. The Arduino nano motor serves to rotate the eggs so that the embryos do not stick to the eggshells.

In the research (Jufril et al. 2015), an automatic chicken egg hatching machine was created using Arduino Uno-based Fuzzy Logic control (FLC) and SHT11 sensors. To view the temperature data detected by the temperature sensor, LCD (Liquid Cristal Display) was used. Of the eight eggs tested, this study only hatched two. This may be due to poor egg quality and PLN power interruptions.

The study (Larasati, Setyaningsih, and Iqbal 2019) made a chicken egg hatcher with a temperature control system using Java programming. This system uses zero-order sugeno-type fuzzy logic control. LM35DZ sensor, arduino microcontroller, and incubator heater are used in this system. The system takes 18.05 minutes to reach steady state with a setting point of 39°C. After steady state and cold outside temperature disturbance, the system can return to steady state in 2.115 minutes.

The study (Iksan et al. 2022) describes how the fuzzy logic mamdani algorithm is used to control the temperature and humidity inside the egg hatching chamber. This tool uses ESP32 as the main controller and DHT22 sensor to control temperature and humidity. By using a fuzzy logic system, the settings can maintain temperature and humidity at 37-39°C and 55-60% RH, with a tool success rate of 88%.

In fuzzy logic research (Maulana et al. 2023), a DHT22 sensor was used to control the temperature and humidity of an egg hatching machine. The study was conducted five times using both fuzzy logic methods, the Sugeno method and the Mamdani method, and the results showed ripples and fluctuations. The system took 302 seconds to reach a stable humidity level and 342 seconds to reach a stable temperature. The humidity MSE is 5.2929, and the temperature MSE is 1.7153.

Previous studies have involved a series of performance tests on various modules supporting the automation system. In this research, the DHT11 sensor measures temperature and humidity, generates digital signals, and automatically changes the surrounding temperature and humidity. To measure pessimistic-type temperature, the sensor is equipped with an NTC (negative temperature coefficient) thermistor and an 8-bit microcontroller. The microcontroller processes the two sensors and sends the results to the output pin in a bidirectional single-wire format. The calibration coefficients of the DHT11 sensor are stored in the OTP program memory, which stands for One-Time Program Memory. As a result, the module calculates these coefficients when the internal sensor detects something (Hartono et al. 2017).

NodeMCU is an opensource Internet of Things platform. It consists of the System on Chip ESP8266, made by Espressif System, and the firmware used. It uses the Lua scripting programming language. The term NodeMCU usually refers to the firmware rather than the hardware development kit. The NodeMCU can be analogized to the Arduino ESP8266. The ESP8266 has been incorporated into a small NodeMCU board that has many features, such as a microcontroller and the ability to connect to WiFi, as well as a USB-to-Serial communication chip. Therefore, all that is needed to program is the same USB data cable extension that is used as a data cable and an Android smartphone charging cable (Wijayanti 2022). In this research, the ESP8266 NodeMCU functions as the main controller of the system in the egg hatching machine.

Relay is an electrically operated switch. Relay consists of two main parts, namely coil (electromagnet) and a set of switch contacts (mechanical). Relay uses electromagnetic principles to move the switch contacts, so that it can deliver higher voltage electricity with low electric current (Saleh and Haryanti 2017). Relay serves to activate and deactivate the lights on the egg hatching machine.

This research provides support for previous research through a literature review that includes analysis and understanding of several related studies. With the aim of optimizing the hatching process of chicken eggs through the application of automatic control using Fuzzy Logic. By automatically analyzing and controlling environmental variables, it is expected to increase the hatching success rate, the health of young chickens, and the productivity of the livestock industry. This approach can have a positive impact not only in terms of production efficiency but also in maintaining animal welfare. Through an in-depth understanding of fuzzy logic and its application in automatic control, this research is expected to be an innovative and effective solution in agricultural technology.

METHODS

The research method used in the optimization of hatching chicken eggs with automatic control using fuzzy logic is the experimental method. The experimental method includes a series of experiments with variations of certain variables to observe the system's response to changing conditionsFurthermore, this study is based on the results of literature studies by referring to several reference sources that are relevant to the system developed. One of the reference sources is a journal called "Increasing Chicken Productivity Through Internet of Things-Based Egg Hatching Machine Incubator Technology," which was compiled by Khairul and published in "JMM (Journal of Independent Society)" in 2022 (Muttaqin, Ihsan, and Irawan 2022). In this journal, the DHT11 sensor is used to analyze the temperature of the chickens.

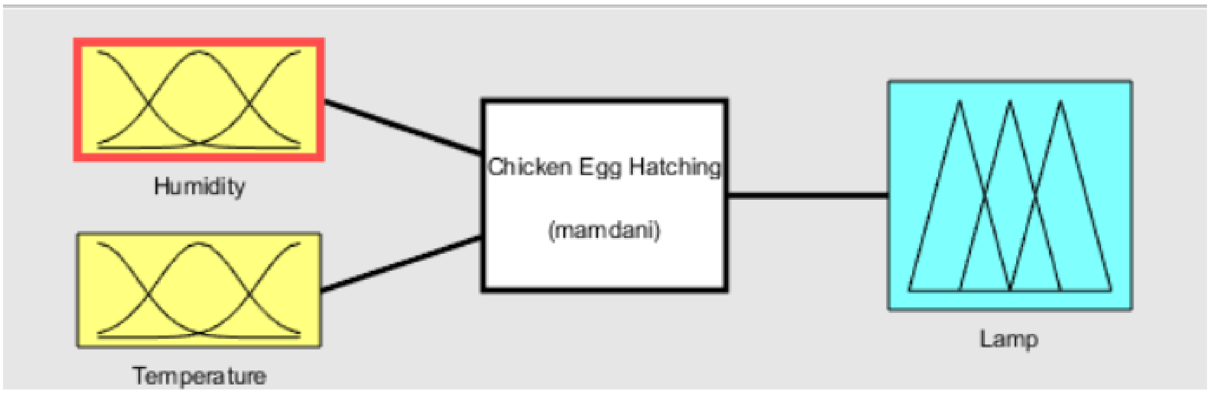

Figure 1. Block Diagram of Chicken Egg Hatching System

Based on Figure 1, the optimization of the hatching process of chicken eggs with automatic control is carried out using two input variables and one output variable. These input variables consist of temperature and humidity measured by the DHT11 sensor. The two input variables together will affect the output variable, which is the condition of the lights on the automatic egg hatching device with the aim that it can operate optimally.

In the design and development of a chicken egg hatching system with automatic control, a series of systematic steps are carried out to achieve the research objectives. The initial step involves analyzing the needs of the chicken egg hatching system by considering the supporting hardware. This research uses the Mamdani method of fuzzy logic. Ebrahim Mamdani developed the Mamdani method in 1975. It is sometimes referred to as the maximum-minimum method. The Mamdani method can accept intuitive input and is based on human reasoning. IF-THEN fuzzy rules support Mamdani implication (Nurdiati, Khatizah, and Rosdiyana 2015; Wawan, Zuniati, and Setiawan 2021). Fuzzy logic is integrated into the system to make adaptive decisions based on the surrounding environmental conditions. In fuzzy logic, linguistic variables are numerical intervals whose values are predictive statements. The linguistic value of a linguistic variable can vary depending on its membership function (Taufik 2016; Wawan et al. 2021). In use, fuzzy logic is used to identify the main variables that affect the hatching process, namely temperature and humidity. The DHT11 sensor is integrated into the system to generate temperature and humidity data as input variables in the fuzzy logic model to be developed. The data analysis process is carried out using the Mamdani fuzzy logic method to control the chicken egg hatching machine.

A fuzzy inference system uses fuzzy logic to create a mapping from the given input to the output (Taufik 2016). The following are the stages of making a Fuzzy Inference System (FIS) mamdani method for optimizing hatching chicken eggs with automatic control.

1. Determine the fuzzy set.
2. The implication function.
3. Defuzzyfication.

RESULTS AND DISCUSSION

In optimizing the hatching process, the main parameters to focus on are temperature and humidity. This is due to the important role of temperature and humidity in determining the success of the hatching process. The input variables that have been determined will undergo conversion into fuzzy variables at the fuzzification stage. This fuzzyfication process involves converting crisp variables into fuzzy variables, according to the procedure described in the literature (Fatkhurrozi, Nisworo, and Sumardi 2022). The fuzzy input variables are presented in fuzzy sets by applying predefined membership functions (Taufik 2016). The Mamdani modul is used to divide a fuzzy set into one or more sets. This membership function describes the membership value in the range 0 to 1 in the fuzzy set. The membership value is applied to give weight to certain variables, allowing the representation of these variables in the form of measurable values (Nurdiati et al. 2015). In this process, there are various forms of curves such as triangular or trapezoidal curves, which can be applied according to the needs of the analysis (Islamiyah and Arifin 2023).

In optimizing chicken egg incubation with automatic control using fuzzy logic, the use of linguistic terms for temperature and humidity inputs as well as lamp output is crucial to optimizing environmental conditions in egg incubation. Table 1 and Table 2 show the Linguistic Terms of the inputs and outputs based on the literature (Lestari, Mulyana, and Mardiati 2020) used to facilitate the operation of the fuzzy control system in the chicken egg incubator with automatic control. For temperature input, linguistic terms such as "Low", "Optimal", and "High" are used to describe the conditions of the incubator temperature. Low temperatures can result in poor egg hatchability, while optimal temperatures are necessary to enhance embryonic survival rates. Meanwhile, humidity is described with the linguistic terms "Dry", "Optimal", and "Moist". Optimal humidity is crucial to ensuring the success of egg incubation, as it can affect the moisture within the egg and embryo health.

Table 1. Linguistic Term of The Input

Input	**Linguistic Term**	**Numerical Term**
Humidity	Dry	[0 0 16 33]
	Optimal	[16 33 49 66]
	Moist	[49 66 100 100]
Temperature	Low	[32 32 35 37]
	Optimal	[35 37 40 42]
	High	[40 42 47 47]

In Table 2, for the lamp output, the linguistic terms "off" and "on" are used to control the lighting inside the incubator. Proper lighting can affect the temperature and humidity within the incubator, which in turn will impact the overall hatching process of chicken eggs.

Table 2. Linguistic Term of The Output

Output	**Linguistic Term**	**Numerical Term**
Lamp	On	[33.8 33.8 35 37.2]
	Off	[35 37.2 39 39]

This research also involves the application of fuzzy logic computationally using MATLAB software to facilitate the prediction process. MATLAB stands for Matrix Laboratory, which is a program specifically designed for numerical analysis and computation and centers on matrices as the basis for its thinking. This program has a variety of uses, but it should be noted that MATLAB performs all mathematical calculations in matrix form (Triawan 2019). In this research, the membership function (MF) graph is the result of data obtained through experts who have conducted previous research. As a membership function representation, the curve shape used in this study is a trapezoidal curve for all variables. This trapezoidal curve is almost the same as a triangular curve, but membership value 1 is more widely distributed or only exists at a few points. The following is the membership function that applies to the trapezoidal curve (Prawira, Poeckoel, and Kambey 2018).

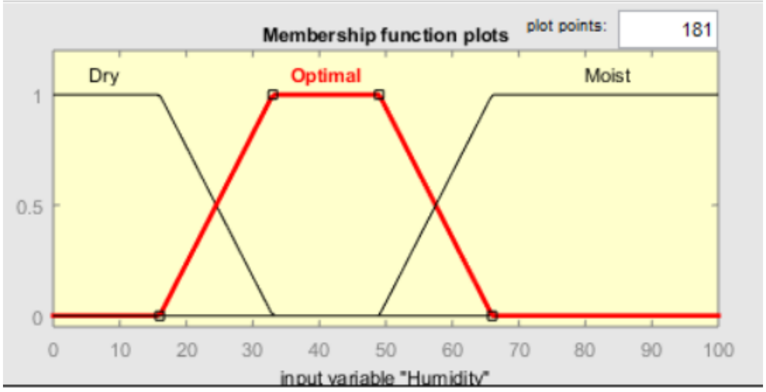

Figure 2. Membership Function Input Variable Humidity

The membership function (MF) of the humidity variable in Figure 2 shows three curves with a range of 0%-100%, which have a trapezoidal shape. The three curves represent the values for each parameter used in the humidity input variable, namely Dry, Optimal, and Humid. The Dry parameter value is in the range of 0%-33%, with the peak point being between 16%-33%. The Optimal parameter value ranges from 16%-66%, with the peak point being between 33%-49%. The Humid parameter value covers a range of 49%-100%, with the peak point being between 66%-100%.

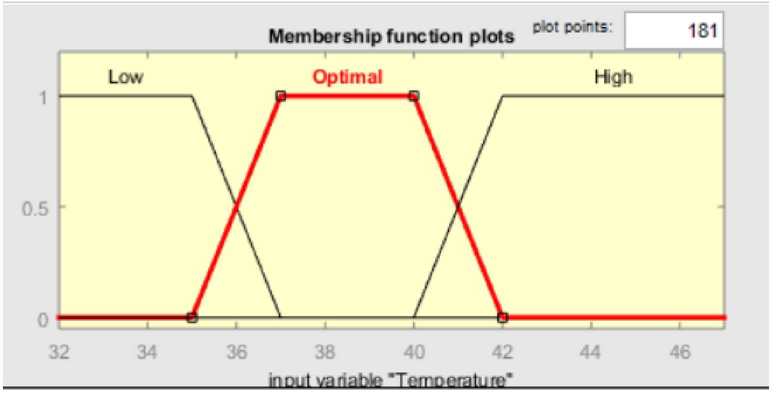

Figure 3. Membership Function of Temperature Input Variable

The membership function (MF) of the temperature variable in Figure 3 shows three curves with a range of 32℃-47℃ that have a trapezoidal curve shape. The three curves represent the values for each parameter used in the temperature input variable, namely Low, Optimal, and High. The Low parameter value ranges from 32℃-37℃, with the peak point being between 32℃-25℃. The Optimal parameter value is in the range of 35℃-42℃, with the peak point being between 37℃-40℃. The High parameter value covers a range of 40℃-47℃, with the peak point being between 42℃-47℃.

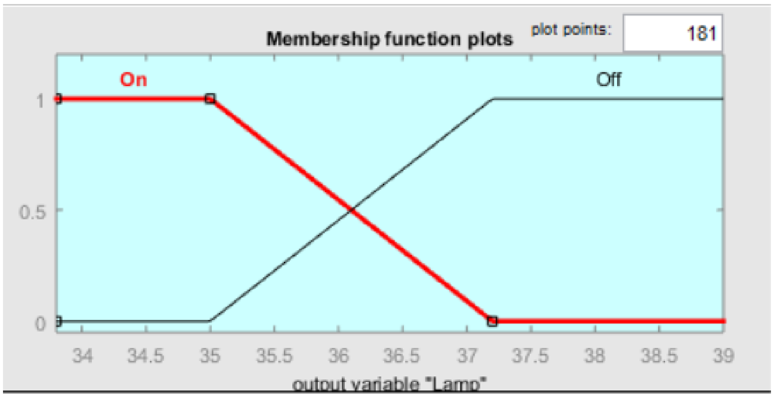

Figure 4. Membership Function Variable Output Lamp Power

The membership function (MF) of the lamp power output variable in Figure 4 shows two curves with a range of 33.8watt-39watt that have a trapezoidal curve shape. The two curves describe the value for each parameter used in the lamp condition output variable, namely On and Off. The On parameter values range from 33.8watt-37.2watt, with the peak point being between 33.8watt-35watt. The value of the Off parameter is in the range of 35watt-39watt, with the peak point being between 37.2watt-39watt.

Hatching chicken eggs with automatic control has several rules that guide the defuzzyfication process. These rules are arranged by multiplying the number of parameters by two or more input variables. Each input variable in this study has 3 parameters, so the number of rules that can be made is 3x3 = 9 rules. The following is a list of rules that have been determined based on input variable data and output variables:

Table 3. Fuzzy Logic Rules

Rules	Input		Output
	Humidity	Temperature	Lamp Condition
R1	Dry	Low	On
R2	Optimal	Low	On
R3	Moist	Low	On
R4	Dry	Optimal	On
R5	Optimal	Optimal	On
R6	Moist	Optimal	On
R7	Dry	High	Off
R8	Optimal	High	Off
R9	Moist	High	Off

Software testing is carried out with the aim of ensuring the suitability of the fuzzy logic model applied to the chicken egg hatching machine. The test was carried out by comparing the results of manual calculations and the results of calculations using MATLAB software against the results obtained from the fuzzy control system of the automatic egg hatching machine built. To carry out the test, the machine conditions are set at 50% humidity and 38℃ temperature. The fuzzy control system will provide output in the form of lamp condition values. To calculate the fuzzy control system manually in this study, it is necessary to perform several steps which will be discussed in detail next.

Determine the fuzzy set

Based on the above treatment, the humidity of the machine is 50%. In Figure, it can be stated that the humidity level of 50% belongs to the optimal and Humid parameters. Therefore, we will calculate the truth value of the membership function for the optimal and humid parameters for a humidity level of 50%. The details of the calculation will be explained in the following description.

$$\mu Optimal_{[50]} = \frac{66-50}{17} = 0.9411$$

$$\mu Moist_{[50]} = \frac{48-50}{-17} = 0.1176$$

Meanwhile, for a temperature of 38℃, based on the figure, it can be stated that the temperature is at the optimal parameter. The membership level by function for temperature is explained as follows.

$$\mu Optimal_{[38]} = 1$$

Implementation of fuzzy implication function

The application of the fuzzy implication function will express the relationship between input and output variables. The equation of each rule in the implication function, namely:

$$IF\ (x_1\ is\ A_1)\ and\ (x_2\ is\ A_2)\ THEN\ y\ is\ B$$

where A and B are fuzzy sets, while x and y are fuzzy variables. The proposition that follows IF is called antecedent, while the proposition that follows THEN is called consequent (Nurdiati et al. 2015).

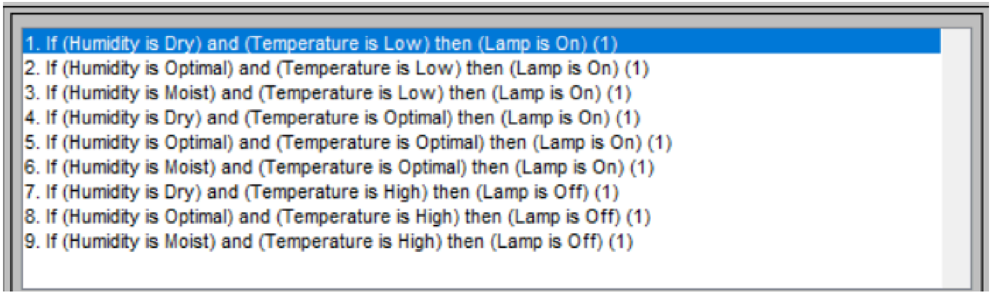
1. If (Humidity is Dry) and (Temperature is Low) then (Lamp is On) (1)
2. If (Humidity is Optimal) and (Temperature is Low) then (Lamp is On) (1)
3. If (Humidity is Moist) and (Temperature is Low) then (Lamp is On) (1)
4. If (Humidity is Dry) and (Temperature is Optimal) then (Lamp is On) (1)
5. If (Humidity is Optimal) and (Temperature is Optimal) then (Lamp is On) (1)
6. If (Humidity is Moist) and (Temperature is Optimal) then (Lamp is On) (1)
7. If (Humidity is Dry) and (Temperature is High) then (Lamp is Off) (1)
8. If (Humidity is Optimal) and (Temperature is High) then (Lamp is Off) (1)
9. If (Humidity is Moist) and (Temperature is High) then (Lamp is Off) (1)

Figure 5. Rule of Egg Hatching System

In this case, nine rule bases are needed to model the relationship between three variables: humidity, temperature, and lamp condition. Each rule maps a combination of input values to a corresponding output value. The number of rules used in this system is based on the complexity of the relationship between the input and output variables to be modeled, as well as the need to cover a wide range of possible input conditions. By using nine rules, we can describe the various possible combinations of humidity, temperature, and lamp conditions that can affect the output of the system. More rules can add complexity to the model and allow the system to handle more different test cases, but they can also increase computational requirements and programming complexity. The number of rules used is usually the result of evaluating the system requirements and analyzing the effectiveness of the model in handling different situations.

In this research, the Mamdani model is applied using the MIN function with the AND operator in each rule. This method takes the smallest membership value of all the membership set parameters involved. Only two rules, namely R5 and R6, were applied out of the nine rules shown in Table 3. The detailed calculations associated with this step will be elaborated on more as follows:

R5 = if Humidity is Optimal **and** Temperature is Optimal **then** Lamp is On

$$[\alpha 5] = \mu Optimal \cap \mu Optimal$$
$$= (\mu Optimal \cap \mu Optimal)$$
$$= (0.9411,\ 1) = 0.9411$$

R6 = if Humidity is Moist **and** Temperature is Optimal **then** Lamp is On

$$[\alpha 6] = \mu Moist \cap \mu Optimal$$
$$= (\mu Moist \cap \mu Optimal)$$
$$= (0.1176,\ 1) = 0.1176$$

Defuzzyfication

The final stage in a fuzzy logic system is defuzzyfication. The output of the defuzzyfication process is a number in the domain of the fuzzy set, so if the fuzzy set is given in a certain range, then a certain crisp value must be taken as output. When the output membership function is symmetrical, defuzzyfication is performed using defuzzyfication based on a weighted average (defuzzyfication weighted average) (Anggun, Marisa, and Dharma 2016). In this defuzzyfication stage, the centroid method is used to identify the area and moment.

$$Z^* = \int \frac{\mu_x(z)dz\ (moment)}{\mu_x(z)dz\ (area)}$$

Next, the area and moment of the lamp power output are searched. In this research, there are two areas and moments of power at the lamp output that will be summed up.

The output area on lamp power

$$A_1 = 34.7 \times 0.92 = 31.279$$
$$A_2 = \frac{37.2-35}{2} \times 0.92 = 1.012$$

$$\sum A = 31.279 + 1.012 = 32.291$$

The output moment at lamp power

$$M_1 = \int_{33.8}^{34.75} 0.92z\, dz = 29$$

$$M_2 = \int_{34.75}^{37.2} \frac{37.2-z}{45} z\, dz = 96.9$$

$$\sum M = 29 + 96.9 = 125.9$$

To find out the value of lamp power output, the equation is used as below:

$$Z^* = \frac{\int_{33.8}^{34.75} 0.92z\, dz + \int_{34.75}^{37.2} \left(\frac{37.2-z}{45}\right) z\, dz}{\int_{33.8}^{34.75} 0.92z\, dz + \int_{34.75}^{37.2} \left(\frac{37.2-z}{45}\right) z\, dz} = 34.4$$

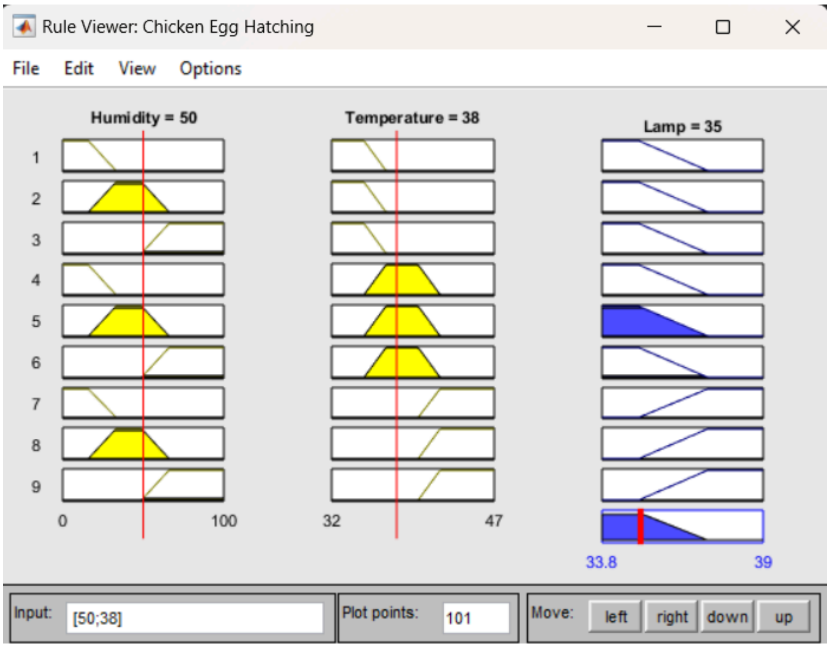

Figure 6. Rule View Defuzzyfication Result of Egg Hatching System

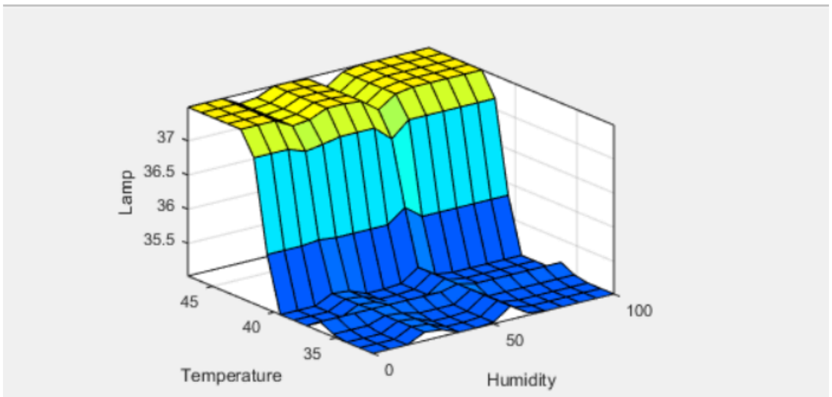

Figure 7 Surfice ANFIS Optimization of Hatching Chicken Eggs

After performing manual calculations of the lamp power value generated in conditions of 50% humidity and 38℃ temperature, the resulting lamp power is 34.4 watts. These results are then compared with the simulation results using MATLAB software. Based on the same data, computational calculations using simulation obtained lamp power of 35 watts according to the illustration in Figure 6.

CONCLUSION

Optimization of Chicken Egg Hatching with Automatic Control Using Fuzzy Logic has successfully determined the optimal conditions of temperature and humidity in an automatic chicken egg hatching machine. The mamdani fuzzy model used can calculate variations in temperature and humidity in the hatching machine and provide recommendations for optimal lamp power. Based on the research that has been done Hatching Chicken Eggs with Automatic Control Using Fuzzy Logic on the results of manual calculations with 50% humidity and a temperature of 38 ℃ is 34.4 watts, while with MATLAB simulation calculations obtained 35 watts. The resulting difference between manual calculation and MATLAB simulation calculation is not too large, only 0.6, which means that the fuzzy logic model implemented is consistent and has a high level of accuracy in predicting the hatching of eggs.

It is hoped that the results of this research will help develop more efficient chicken egg incubator technology that improves the quality and quantity of chicken production. In addition, this research can be applied to other areas of animal husbandry. However, there are some limitations to this research that need to be considered for future research, such as the influence of other variables that have not been taken into account and increasing the accuracy of fuzzy logic models. Therefore, it is expected that future research can focus on the integration of temperature and humidity sensors that are more precise for real-time environmental condition monitoring, thus improving egg incubation efficiency. Additionally, further research could include more extensive analysis of other environmental variables affecting the egg incubation process, such as air ventilation and air quality around the incubator, to optimize overall environmental conditions and increase embryo survival rates.

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