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Design of a Mamdani Fuzzy Logic Prototype System for Free-Range Chicken Egg Incubators

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ABSTRACT: *This research aims to design a temperature and humidity control system for chicken egg incubators using the Mamdani Fuzzy logic method. The main problem addressed is the fluctuation of temperature and humidity in conventional systems that still rely on on/off control. The developed system utilizes DHT sensors as temperature and humidity gauges, Arduino as a microcontroller, and regulates the light intensity of incandescent lamps using an AC dimmer. Mamdani Fuzzy Logic is used to process two inputs, namely temperature and humidity and produce an output in the form of the brightness level of the incandescent lamp. The system relies on nine Fuzzy rules in making decisions based on variations in input conditions. The test results show that the system is able to provide appropriate responses to changes in temperature and humidity, and produce outputs in accordance with the designed rules, such as Rule R1, R5, and R9. Thus, this system succeeds in maintaining the stability of the temperature in the incubator, so as to increase the efficiency and success of the egg hatching process. Overall, the application of Mamdani Fuzzy Logic proved effective in designing an intelligent control system for the incubator.*

KEYWORDS: *Arduino, Fuzzy Mamdani, Incandescent Lamp.*

I. INTRODUCTION

In this era of rapid technological development, there is a need for systems that are not only capable of controlling but also monitoring, thereby bringing convenience to human life in various fields. Chicken farms can use conventional hatching machines to hatch chicken eggs quickly and efficiently[1] . The process of hatching poultry eggs, especially native chicken eggs, requires special attention to ensure success[2] . Modern egg incubators are not only designed to automatically maintain temperature and humidity, but also provide *real-time* data on the condition of the eggs during the incubation process. Therefore, an innovation is needed to help farmers simplify the egg production process. This innovation is in the form of an egg incubator.

The use of incubators allows for increased production scale and hatching success rates, as environmental factors such as temperature and humidity that affect the hatching process can be controlled more accurately[3] . In the chicken egg hatching industry, temperature stability is a crucial aspect that needs to be considered, especially when using artificial incubators that still rely heavily on On/Off control systems. The use of this type of control tends to result in a slow response in reaching *a steady state*[4] . One of the most commonly used methods in control systems is Fuzzy Logic. This method is known as a form of intelligent control because it is able to determine variables based on an approach that resembles human thinking[5] .

The Fuzzy Logic method works by using linguistic rule sets to regulate input and output variables based on human experience or knowledge. Fuzzy Logic is widely used in systems because it is flexible and can adapt to changes and uncertainties in a problem [6] . In this study, input variables such as temperature and humidity read by the DHT sensor will be processed by the Fuzzy system to produce an output in the form of light. MATLAB is used as a simulation tool that allows researchers to run experiments repeatedly and consistently in a controlled environment. This platform also supports quantitative measurement and analysis of time response, temperature stability, and energy efficiency, while enabling control of important variables to ensure the internal validity of the research[7] .

This incubator system is designed using an Arduino microcontroller as the main processing unit that automatically controls the temperature. The temperature sensor monitors the temperature conditions inside the incubator in real-time, then the data is sent to the microcontroller to be processed using the Fuzzy Logic algorithm. The method applied is Fuzzy Logic, which will then be combined and implemented into the Arduino microcontroller[8] . When the temperature is below the optimal threshold, the system will turn on the incandescent lamp. Conversely, if the temperature approaches or exceeds the upper limit, the light intensity will be reduced or turned off completely. This approach allows for a more subtle response to temperature changes compared to conventional ON/OFF control systems. This research designs and develops an intelligent control system for native chicken egg incubators, with a primary focus on temperature stability as the key to successful hatching. This system integrates sensor technology, Arduino microcontrollers, and Fuzzy Logic methods. Fuzzy Logic itself is effective in controlling room temperature to maintain temperature stability. One commonly applied model is Fuzzy Mamdani, which is known as a flexible decision-making method capable of handling data uncertainty well[9].

This system is expected to maintain the incubation temperature within the ideal range consistently. The application of Fuzzy Logic provides flexibility in decision making regarding temperature fluctuations, thereby potentially increasing the success rate of egg hatching and minimizing the risk of failure during the incubation process.

II. THEORETICAL BASIS

A. MAMDANI FUZZY

The Mamdani method, also known as the Max–Min method, was first introduced by Ebrahim Mamdani in 1975. To produce output, this method goes through four main stages [10], namely:

1) Formation of Fuzzy Sets

In this stage, both input and output variables are classified into one or more fuzzy sets.

2) Application of Implication Functions

In the Mamdani method, the implication function used is the Min function, which is used to determine the degree of fulfillment of a rule.

3) Rule Combination

Unlike monotonic reasoning, if the system has several rules, the inference process is carried out by combining and analyzing the relationships between these rules. There are three main approaches in the fuzzy inference process: the Max method, the additive method, and the probabilistic OR (probor) method.

4) Defuzzification

The defuzzification process receives input in the form of a fuzzy set generated from a combination of rules and converts it into output in the form of a *crisp* value. In other words, from a fuzzy set within a certain range, one definite value must be taken as the final result.

III. RESEARCH METHOD

This chapter discusses the research method, covering the hardware and software systems. The temperature and humidity in the native chicken egg incubator are controlled according to the requirements specified in the three test samples. This fuzzy research method plays an important role in regulating the temperature and humidity range based on predetermined parameters.

A. FORMATION OF FUZZY SETS

Figure 1 below shows the input and output scheme for a system using the Mamdani method, with two input variables, namely temperature and humidity, and one output variable in the form of a light. The values detected by the temperature and humidity sensors will affect the output level of the light in accordance with the applied Fuzzy Logic.

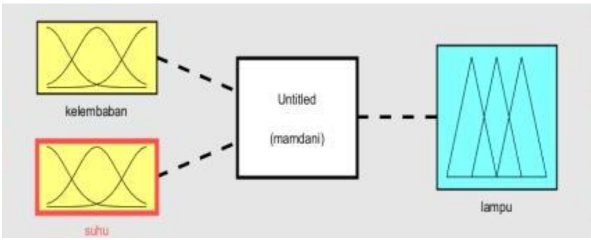

Fig. 1 . Mamdani Fuzzy Input and Output

1) Input

- Humidity

Humidity Range: 0% − 100%
Dry: 0-35%
Normal: 35-60%
Humid: >60%

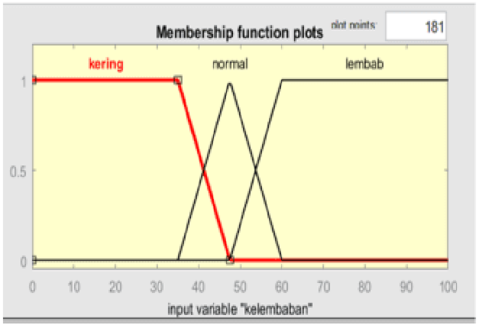

Fig. 2 Humidity Range

- Temperature

Temperature Range: 0% − 100%
Cold: 0-37°C
Warm: 37-38.5°C
Hot: >38.5°C

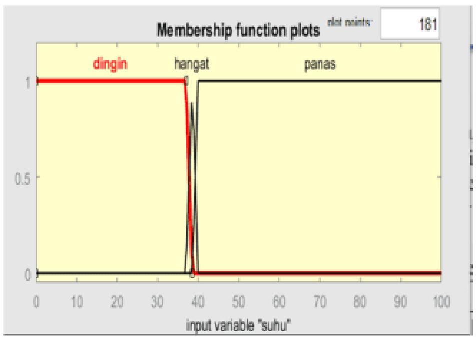

Fig. 3 Temperature Range

2) Output

- t Incandescent Light

Intensity Range: 0 – 255
Dim: 0-42
Normal: 43-126
Bright: 127-255

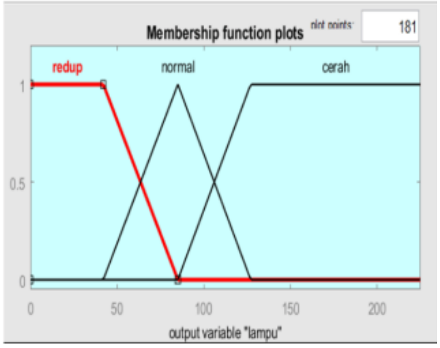

Fig. 4 Light Intensity Range

B. APPLICATION OF THE IMPLICATION FUNCTION

This lighting control system uses Fuzzy Logic as the basis for decision making, where the control process is not carried out through a conventional flowchart, but through a number *of* rules that have been designed systematically. These rules represent the relationship between temperature and humidity conditions and the intensity of incandescent light. In this system, temperature is categorized into three conditions, namely *cold, warm,* and *hot,* while humidity is divided into *dry, normal,* and *humid.* The output of this system is the level of incandescent lighting, which is divided into *bright, normal,* and *dim.* The following is a table of rules:

Tbl 1. System *Rules*

Rule	Temperature	Humidity	Incandescent Lamp
R1	Cold	Dry	Bright
R2	Warm	Dry	Normal
R3	Hot	Dry	Dim
R4	Cold	Normal	Bright
R5	Warm	Normal	Normal
R6	Hot	Normal	Dim
R7	Cold	Humid	Bright
R8	Warm	Humid	Normal
R9	Hot	Humid	Dim

There are nine logic rules (R1 to R9) that form the basis of the system's decision-making. For example, if the temperature *is cold* and the humidity *is dry* (R1), the incandescent lamp will shine *brightly*. Conversely, if the temperature *is hot* and the humidity *is humid* (R9), the light will glow *dimly.* By applying this logic, the system is able to provide adaptive and efficient lighting responses to changes in environmental conditions.

C. BLOCK DIAGRAM

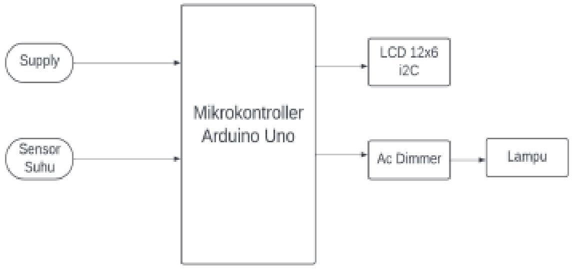

Fig. 5 Block Diagram

Figure 5 shows a temperature-based lighting automation system controlled by an Arduino Uno microcontroller. This system works by receiving input from two main components, namely the power supply and the temperature sensor. The temperature sensor measures the ambient temperature and sends the data to the Arduino Uno. The microcontroller then processes the received data and adjusts the output as needed. The output of this system consists of two parts, namely a 12x6 i2C LCD and an AC Dimmer. The LCD displays real-time temperature information, while the AC Dimmer regulates the brightness of the lights based on the detected temperature. The lights connected to the AC Dimmer will turn on with adjusted intensity, so this system can be used for applications such as room temperature control, incubators, or automatic lighting systems.

IV. RESULTS AND DISCUSSION

A. IMPLEMENTATION OF THE PROTOTYPE SYSTEM

To operate the incandescent light control system, several system components are required, including hardware such as a laptop or computer and a USB downloader, as well as software in the form of Arduino IDE. The following is a diagram of the system wiring:

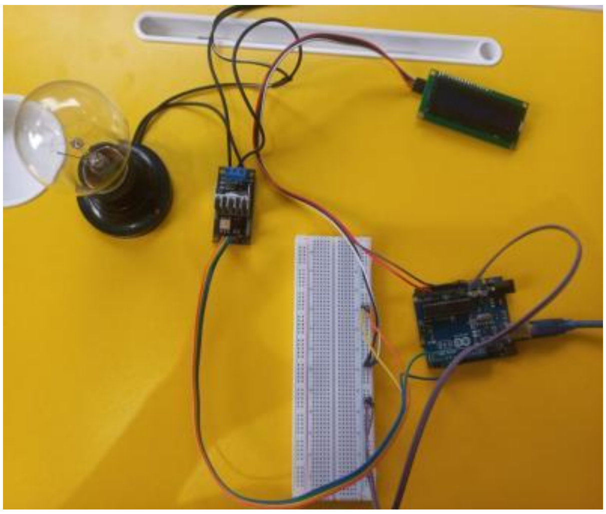

Fig. 6 System Wiring

B. SYSTEM TESTING

During the system testing phase, several testing stages were carried out so that the results obtained could be reanalyzed to determine whether the system was running according to the available data. Sensor Testing Sensor testing was carried out to determine the results that had been analyzed in the existing data. Table 2 below shows the sensor and lamp testing results.

Tbl 2. Testing

Testing	Temperature	Weakness Lamp	Light	Key
1	39	57		Normal
2	44	76		Dim
3	24	31		Bright

Next, in the second test, the temperature was recorded at 44°C and the humidity at 76%, which is classified as hot and humid. These conditions correspond to Rule R9, which states that if the temperature is hot and the humidity is humid, the lamp must turn on with dim intensity. The test results show that the light turns on dimly, so the system again produces an output that complies with the rule, namely Rule R9.

In the third test, the temperature was recorded at 24°C and the humidity at 31%. Based on the Fuzzy logic classification, a temperature of 24°C falls into the cold category, and a humidity of 31% is categorized as dry. This combination of conditions complies with. Rule R1, namely: cold temperature and dry humidity, with the expected output being that the lamp turns on at full intensity. The test results show that the light does indeed turn on in bright conditions, so the system produces an output that complies with *rule* R1. This indicates that the Mamdani Fuzzy system is capable of processing temperature and humidity inputs accurately ( ) and applying the appropriate rules according to environmental conditions.

From the two tests, it can be concluded that the Mamdani Fuzzy system is capable of performing the inference process based on the rule base accurately, in accordance with the combination of temperature and humidity values detected by the sensor.

C. TEST ANALYSIS

Based on the results of the Mamdani Fuzzy system testing, it can be analyzed that the output produced is in accordance with the designed logic *rules*. In the first test, the ambient temperature was recorded at 39°C and the humidity at 57%. Based on the classification criteria, this temperature falls into the warm category and the humidity is normal. This combination of conditions corresponds to Rule R5, namely: warm temperature and normal humidity, with the expected output being a lamp with normal intensity. The test results show that the lamp does indeed turn on under normal conditions, so the system is working in accordance with Rule R5.

V. CONCLUSION

A. The Mamdani Fuzzy Logic-based temperature and humidity control system was successfully applied to a chicken egg incubator by integrating temperature and humidity sensors, Arduino, and an AC dimmer to regulate the intensity of the lamp as a heater.

B. There are nine Fuzzy *rules* built based on the combination of temperature and humidity to produce the appropriate light level (bright, normal, dim).

C. Test results show that the system produces outputs consistent with the designed rules:

1) *Rule* R5 (Warm, Normal → Normal)

2) *Rule R9 (Hot, Humid → Dim)*

3) *Rule* R1 (Cold, Dry → Bright)

D. D. The system is able to adapt to changes in temperature and humidity in a responsive and smooth manner compared to conventional *on/off* methods.

E. E. This system has the potential for further development with the addition of active humidity control and IoT-based remote monitoring.

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