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Egg Incubator Temperature and Humidity Control Using Fuzzy Logic Controller

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Abstract

Controlling room temperature and humidity in egg incubator systems is a process that is widely used in the farm. A good temperature and humidity for standard egg hatching is between 35℃ – 40℃, with humidity in the machine ranging from 50%-60%. The main problems of our research is to find the robustness of the fuzzy logic controller, using the proper parameter. Because while the particular parameter is applicable for one case, but after using several times, the controller lost its robustness. Therefore, this study aims to create a system to control the temperature and humidity of the egg incubator with fuzzy control using the Sugeno methods. In order to get the input and output values, namely by connecting the DHT22 sensor to measure temperature and humidity to be processed into the microcontroller, the value obtained from the sensor will then be processed. The use of fuzzy control is used to make several stages, namely fuzzification, rule, and defuzzification which after processing will be used as output weights for the actuators used. In order to get the robust parameter, test was carried out 5 times with a test time of 18 minutes to get a stable value from the tool. By applying this, it can be concluded whether the system is reliable during different situation. The result shows that the average time for the system to get a stable humidity is 302 second. On the other hand, the average time for the system to get stable temperature is 342 second. The Mean Squared error for temperature is 1,715, while the Mean Squared Error for Humidity is 5,294. It can be concluded that the system controlled by fuzzy controller is robust, has a fast response and reliable.

Keywords: *egg incubator; fuzzy controller; mean squared error; temperature; humidity*

1. Introduction

The Reports on the results of the National Socio-Economic Survey (Susenas) in the first quarter of 2013 and the first quarter of 2014 the development of the average consumption of broiler eggs and native chickens per week of capital from 2015-2016 tends to increase by 3.75%, and consumption of chicken meat race, the average chicken increased 8.01% [1], [2].

From this description, it can be said that technological developments in the electrical field show very significant developments, for example in an automatic control system for regulating temperature and humidity in a room. The automation system for controlling the temperature and humidity of the air in the incubator is a process that is widely used in the livestock industry. The temperature regulation process that affects the temperature and humidity of the air in the incubator room will have to have a fairly low error value because the room temperature will greatly affect the eggs. The temperature and humidity used for egg hatching standards are between 35℃ – 40℃, with humidity in the machine ranging from 50% – 60%. The main problems of our research is to find the robustness of the fuzzy logic controller, using the proper parameter. Because while the particular parameter is applicable for one case, but after using several times, the controller lost its robustness. So, by using several trials, the robustness can be analyzed.

In the egg incubator which is now familiar to farmers in Indonesia, there are already many in the market where with this technology eggs can be incubated in large numbers, so that the market needs of chickens in the market can be met. However, there are still many egg incubators currently circulating that cannot work automatically, these incubators still require human labor so they still require operators and take time. In the development of technology, humans want something that works automatically [3].

In this study, we will discuss the system that is expected to function to overcome these problems. This system is made using fuzzy control technology. The reason why this research using Fuzzy Logic Controller, because this

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type of controller can be easily adjusted in a different circumstance of the system. The model of the system can be obtained using empirical methods. So that, many figure 1factors that can change the behaviour of the system such as noises and changing in surrounding parameter is already included in the empirical models.

Fuzzy logic method is one method that can be developed and applied to incubators using fuzzy logic. Fuzzy logic is one of the components that make up Soft Computing. The basis of fuzzy logic is fuzzy set theory. The role of the degree of fuzzy membership is to determine the existence of elements in an important set. Then there is the degree of membership or membership function which is the main characteristic of reasoning with fuzzy logic [4]. The fuzzy method itself has 2 methods, namely Mamdani and Sugeno. In simple terms, the Mamdani method is a useful method for drawing conclusions and making the best decisions on the problems at hand, while the Sugeno method is more or less the same except that this method has an output that is not a fuzzy set but in the form of constants or linear equations. Therefore, this research is intended to solve the problems that have been described, as well as to test the fuzzy method as decision making to control the parameters being tested. In this research, the methods that is chosen is sugeno methods. There are several reason why this method is chosen. The sugeno methods has more flexibility compare to mamdani methods. On the other hand, because this controller is created using programs, in this terms the Sugeno FIS is more easily applied because there is no need to use the sophisticated defuzzification process from Mamdani type. Instead, it can be replaced with a weighted average.

Paper [1] and [2] conducted research on a temperature control system in the egg hatching process whose heating element utilizes a heater. in the condition of the system that has a disturbance, it takes a relatively long time, namely for 126.9 seconds. In these two studies, fuzzy logic is used to obtain the membership degree value of the egg type, which will later be used as a determinant of temperature and humidity output. The results of this study found that the application of fuzzy logic has an average error percentage value of 0.016% and the whole fuzzy logic final calculation system to determine the type of egg has an error percentage of 0.001% with the overall actuator conditions are in accordance with the specified.

Then research related to temperature and humidity using the fuzzy method with different media, namely, [3] and [4] which both used room media to control temperature and humidity. This research focuses on different rooms to control temperature and humidity according to different set points and standards to get good quality. By using a different sensor as a measuring instrument to get a value that will later be processed as input data into output data on the microcontroller used in [5] [6], and [7] From the research conducted in each room, it is very important to ensure the temperature and humidity that exist to maintain the condition of equipment and components so that corrosion does not occur. By utilizing the fuzzy method as decision making as a controller and monitoring, it is expected to get the desired results. Each room also has a different ideal temperature to ensure the controlled parameters are as expected so that the existing equipment does not experience negative impacts from inappropriate temperature and humidity.

Research [8] examined the application of fuzzy logic to an egg warmer system with a DHT22 sensor used as temperature and humidity readings. with a microcontroller as a controller to increase the work efficiency of the tool. And in the last test, namely testing temperature and humidity at one time where temperature and humidity are inversely proportional to testing whether the fuzzy controller is able to maintain a balance between temperature with a range of 36 - 40 and humidity with a range of 65 - 75% RH as desired, then The results obtained are quite stable with the desired set point, the system design to control temperature and humidity with fuzzy logic functions is declared successful.

In the research [9], [10], [11], using different controllers which is PID controllers. Those Controllers work properly, but different types of controllers are needed. In [12] and [13], the fuzzy logic are used to control only in parameter, which is the temperature. So, it is still needed to use and additional parameter, namely humidity. In [14], additional parameter that used is light intensity.

Research [15] was applied to the first 15 days of chicks, and used zero crossing methods, other methods are still needed.In [16], there already humidity and temperature controllers. But this research using on and Off controller, and can still be enhanced using more sophisticated controller. In [17], the controller already using fuzzy logic to control humidity and temperature. The conclusion that it reach sufficient setting, but still can be improved by using different modules, but it still can hatch the egg using sufficient setting [18].

Fuzzy based on timer for eggs incubator was used in [19]. It can be concluded that the right timing can greatly affect the outcome. In [20], the hybrid of Fuzzy and PID controller significantly improve the performance for the system to reach temperature set poin. But in this research, the difficulty to achieve a normal temperature while getting a disturbance from changes of humidity is still exist.

In research [21], using Fuzzy Logic controller, there was a significant overshoot value that reduce the performance. In research [22], the basic using of on off

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controller was used. Thus, there is still rooms for improvement.

This research is conducted because the reliability of the controller is still a big issue. It needs to be analyzed whether the same controller can work properly for several measurement. So, because eggs incubator usually used several times in a year, it needs to be analyzed whether it has a sufficient reliability or not.

The state of the art for this research is that there is still gap in the research of reliability of the controller after used several times. So, the performance of the controller after several usage needs to be analyzed.

2. Research Methods

2.1 Hardware Configuration.

Figure 1 shows the block diagram of the system that is used in this research. The temperature and the humidity of the egg incubator system is measured using DHT 22 Transducer. The result is sent to Microcontroller ESP 201. In the Microcontroller, fuzzy logic controller algorithm is applied. The result is sent to PWM driver that will activate Lamp to and Fan to control the temperature, and humidifier modules to control humidity.

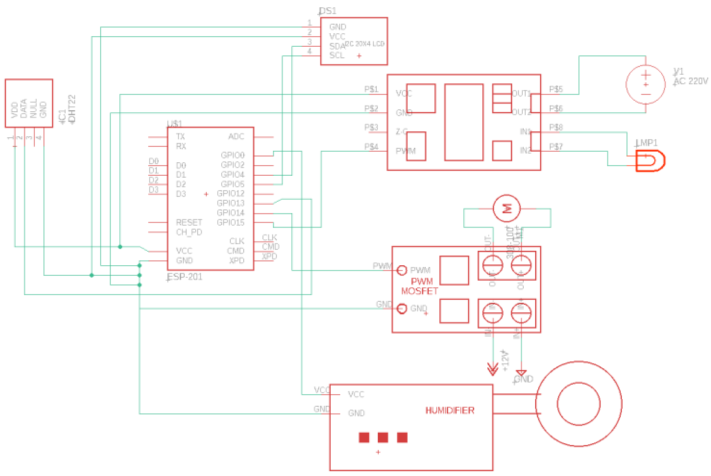

Figure 1. Schematic diagram of Egg Incubator system

System design steps: Connect the temperature and humidity sensors with the microcontroller; The microcontroller will process 2 inputs from the temperature and humidity values in the incubator room into a voltage value; Designing fuzzification inputs by creating several membership functions; Designing rules in accordance with the fuzzification made according to the membership function created; Designing defuzzification to change the input data that has been entered in the fuzzy set to regain its firm form; Output from fuzzy is connected to all motor DRIVER; Designing PWM for motor DRIVER to control motor speed; The output from the DRIVER motor will be connected to all actuators in the form of lights, fans, and humidifier modules. The Eggs incubator Prototype is shown in figure 2. All transducer and actuator already integrated inside the prototype.

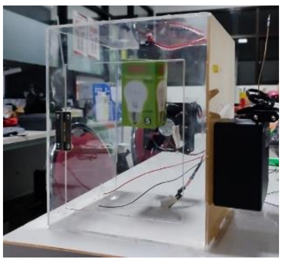

Figure 2. Egg Incubator Prototype.

2.2 Software Configuration

There are different types of Fuzzy Logic Controller, the Mamdani-type and the SUGENO-type. Based on the usage of those two types, the Mamdani FIS is more commonly used, because it provides acceptable results even though the structure is simple. However, the SUGENO FIS's rules' has its ow advantages in term of the easily adjusted parameters. Because the parameters are easily adjusted, there are more degrees of freedom while designing the controller compare to Mamdani type. So, it can be concluded that sugeno type gives more flexibility. The sugeno type also has more computational efficiency and accuracy compare to the mamdani type. And it is a huge difference because this research using programs to design the fuzzy controller system.

The implementation of the software used in this study is the Arduino IDE software.The program that has been created contains the fuzzy logic method used in this research starting from Fuzzification, FIS (Fuzzy Inference System) or Rule, and Defuzzification. The fuzzy program used the Sugeno method which presented in the form of IF – THEN. The output results are a set of single fuzzy constants or defuzzification crisps that were made earlier. In the fuzzy program the input is obtained from the sensor reading value, the

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fuzzy method will be used as an output controller to control all actuators used in the in this research to control humidity and temperature.

In designing this input with fuzzification to create fuzzy logic by determining what variables will be included, both of them will be searched for their membership values first. The design of the input values in this fuzzy logic is obtained from the sensor reading values, namely Temperature and Humidity for formula calculations

The temperature parameter has variables for temperature, namely Cold, Normal, Hot. So to determine the value of membership weight is determined by the formula.

Cool Membership Function :

$$\begin{cases} 1, & x \le 32.5 \\ \frac{35.0-x}{0.25} & 32.5 \le x \le 35.0 \\ 0, & x \ge 35.0 \end{cases}$$

Warm Membership Function :

$$\begin{cases} 0, & x \le 35.0 \\ \frac{x-35.0}{0.25} & 35.0 \le x \le 37.5 \\ \frac{40.0-x}{0.25} & 37.5 \le x \le 40.0 \\ 0, & x \ge 40.0 \end{cases}$$

Hot Membership Function :

$$\begin{cases} 0, & x \le 40.0 \\ \frac{x-40.0}{0.25} & 40.0 \le x \le 42.5 \\ 1, & x \ge 42.5 \end{cases}$$

And for the humidity, the membership Function is created in this form:

Dry Membership Function :

$$\begin{cases} 1, & x \le 50 \\ \frac{55-x}{5} & 50 \le x \le 55 \\ 0, & x \ge 55 \end{cases}$$

Average Membership Function :

$$\begin{cases} 0, & x \le 55 \\ \frac{x-55}{5} & 55 \le x \le 60 \\ \frac{65-x}{5} & 60 \le x \le 65 \\ 0, & x \ge 65 \end{cases}$$

Wet Membership Function :

$$\begin{cases} 0, & x \le 70 \\ \frac{x-70}{5} & 70 \le x \le 75 \\ 1, & x \ge 75 \end{cases}$$

The design of controllers with fuzzy logic has quite an important stage, namely making rules which are connecting rules between input and output in a fuzzy set to get a stable response according to the desired parameter results. This design uses the IF – THEN concept, but because what is being done in this research is MIMO (Multiple-Input Multiple-output), the concept will be:

IF (Temperature is …) and (Humidity is …) Then (Fan is …) and (Lamp is …). The rule program is shown in figure 3.

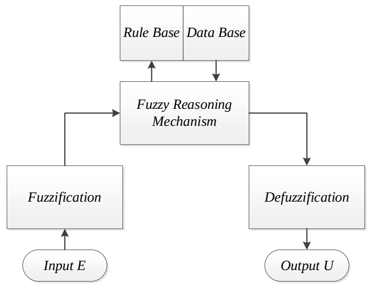

Figure 3. Rule in Fuzzy Controller

In designing this output with defuzzification as a weight value for the output of the actuator with the Speed and Intensity parameters it has variables, for fans namely Fast, Medium, Low while for lights namely Bright, Normal, Dark. For example, the value of the Fast variable will be determined from the weight of the temperature and humidity values, as well as the other variables. Defuzzification is shown in formula 1.

$$f = \frac{W_1.f_1+W_2.f_2+\cdots+W_n.f_n}{W_1+W_2+\cdots+W_n} \quad (1)$$

Variable = Fan/Light Rule [i] × Min Value of Temperature/Humidity Weight

The program for defuzzification is shown in figure 4. The objective of chopping the output is to adjust the actuator speed to match what is desired to get a good response with the given membership function. The desire is in the form of set point for temperature and humidity. The root mean square of error obtained from measured temperature and humidity is calculated and analyzed. The analyzes is conducted during a steady state situation after the time settling is obtained. There are 5 trials for the same setting to measure the robustness of the system.

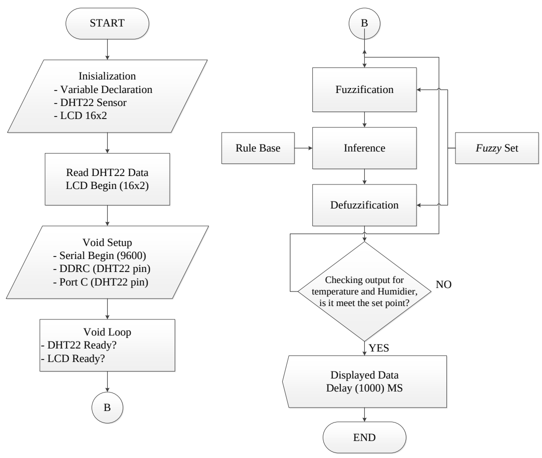

Figure 4. Fuzzy Algorithm

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2.3. Data Acquisition

In the data collection process, five experiments were carried out under the same conditions and when the temperature and humidity in the incubator were similar. Data collection time is 18 minutes and data collection is conducted every 30 seconds. Data collection was carried out for 18 minutes because at 18 minutes the temperature and humidity did not change significantly or the temperature and humidity were stable at that time. In data collection, the set point of temperature and humidity is determined. When collecting data, PWM values from fans and lights are also obtained with a range of 0-100. In this process it is also calculated for the temperature and humidity error values obtained from the controller results. Data retrieval is carried out to obtain some result values such as: Stable Temperature Value, stable Humidity Value, Error RMS value for humidity and temperature.

With these data, the minimum and maximum values of the tested parameters will be obtained and stable results will be obtained as well as errors from the desired set point with the MIMO concept and can also see the performance results of the fuzzy method for controlling the parameters tested on the trototype used. For the calculation of the error value obtained by formula 2. Temperature set point is 38°C, and Humidity set point is 55%.

$$error = \frac{(set\ point - Measurement\ value)}{Set\ point} \times 100\% \qquad (2)$$

3. Results and Discussions

3.1 Sensor Calibration

In testing the sensor used is a DHT22 temperature sensor with a specification of an input voltage range of 3.3 - 6 VDC and a temperature range of -40 - 80°C. In testing the accuracy of the sensor by comparing the sensor readings with a digital infrared thermometer Gs320. The calibration result is shown in Table 1. Based on table 1, the error for temperature measurement and humidity measurement cold be calculated.

Temperature Error:

$$\frac{(27{,}2 - 27{,}4)}{27{,}4} \times 100\% = 0{,}73\%$$

Humidity error :

$$\frac{(60{,}10 - 60{,}0)}{60{,}0} \times 100\% = 0{,}16\%$$

Table 1. Sensor Calibration

No	Temperature (°C)	Humidity (%)	Digital Termometer (°C)	Digital Humidity Measurement (%)	Times
1.	40.5	64.90	40.8	64	1 Minutes
2.	39.2	62.60	39.6	62	2 Minutes
3.	38.8	63.20	39.2	62	2 Minutes
4.	37.4	61.40	38.9	62	4 Minutes
5.	36.6	60.40	37.2	60	5 Minutes
6.	35.1	62.40	36.5	61	6 Minutes
7.	34.5	62.00	35.4	62	7 Minutes
8.	33.2	64.40	34.6	62	8 Minutes
9.	32.9	62.90	33.9	60	9 Minutes
10.	31.8	60.70	33.6	60	10 Minutes
11.	30.5	60.00	31.2	61	11 Minutes
12.	29.7	62.20	30.8	61	12 Minutes
13.	28.2	61.80	29.4	60	13 Minutes
14.	27.6	60.50	28.1	60	14 Minutes
15.	27.2	60.10	27.4	60	15 Minutes

3.2 Temperature and Humidity Response

The data collection was carried out when the initial temperature was roughly 28 °C and the humidity at random situation. At the start of all the actuators have not turned on the temperature and humidity are rated far from the set point, but when the actuators start to turn on the temperature starts to rise and the humidity starts to decrease with fan speed and 100% light intensity. The light that is on will raise the temperature of the incubator room and the rotating fan will reduce the humidity in the incubator room. Figure 5 shows the temperature response from 5 different trials using sugeno methods, while Figure 6 shows us the temperature response using Mamdani methods..

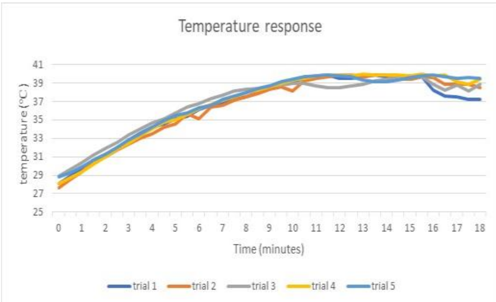

Figure 5. Temperature Response Using Sugeno Methods

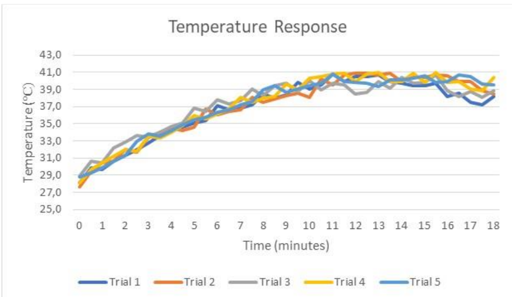

Figure 6. Temperature Response Using Mamdani Methods

In the figure 5, which is using sugeno methods, it can be seen that all trials reach the set point almost in the same time. But after steady, there are differences among the trials existed. But the output still in the acceptable range. But it is shown that during the steady state, every setting has more variations. While, in term of time rise and time settling, figure 6, which is using mamdani methods, did not show us significance difference compare to sugeno methods, but it shows more ripples. It seems that the defuzzification in mamdani is more susceptible with the change in input.

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It is shown that the Sugeno method can be applied here, because the output range is stable even though the temperature outside of incubator is varied. For 5 different trials, the output still meet the expectation. The time rise and time settling is similar, with no overshoot. Which means that in term in robustness, it is applicable for eggs incubator.

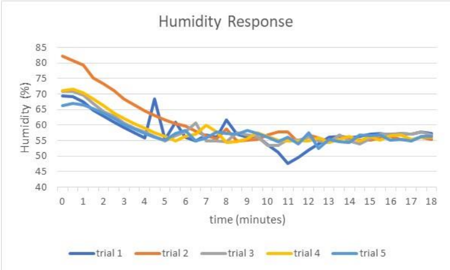

Figure 7. Humidity Response Using Sugeno Methods

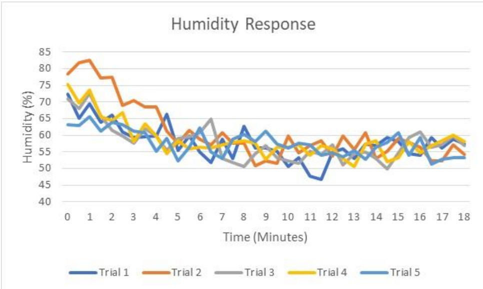

Figure 8. Humidity Response Using Mamdani Methods

The humidity response in Figure 7, which is using sugeno methods, start in different value, but in the end, it still can reach desirable humidity or set point. There are various spikes that occurred, but still in the acceptable range. There is overshoot for one trials, which means that for humidity controller, it is not as robust as temperature controller. So further research related to humidity control is still needed.

On the other hand, in Figure 8, it can be seen that by using mamdani Methods, there is more oscillation compare to Sugeno Methods. But in the end, the output Table 5. Squared error After steady Humidity

is still within the acceptable range. So, by comparing that two different methods, it can be seen that overall, the response by using mamdani or sugeno methods is similar. The difference is the ripple and oscillation that occurred if mamdani method is used. From the response, the time settling can be calculated. The average time settling obtained, for both temperature and humidity response is shown in table 2 and table 3.

Table 2. Temperature Time Settling

No	Trial	Time Setting
1	Trial 1	330 S
2	Trial 2	360 S
3	Trial 3	330 S
4	Trial 4	330 S
5	Trial 5	360 S
Average		342 S

Table 3. Humidity Time Settling

No	Trial	Time Setting
1	Trial 1	510 S
2	Trial 2	480 S
3	Trial 3	210 S
4	Trial 4	240 S
5	Trial 5	210 S
Average		306 S

From those tables, it can be seen that it took longer time to obtain time settling for temperature. But the differences among the trials is not big. On the other hand, it took shorter time to obtain time settling for humidity. But there is big difference among the results of the trials. The average time for the system to get a stable humidity is 302 second. On the other hand, the average time for the system to get stable temperature is 342 second.

The mean squared error also calculated and analyzed. The calculation is obtained after steady temperature is obtained, in order to measure the stability of the temperature. The calculations are using 5 different trials. The result is shown in table 4 for MSE in stable temperature, and table 5 for MSE in stable humidity.

Based on the results above, it can be seen that different trials did not affect output significantly. The MSE for humidity is 5,2949 and the MSE for temperature is 1,71533. So, it can be concluded that the MSE for Humidity is greater than the MSE for temperature. Because but it is still in the acceptable range. The mean squared error for humidity control is still significantly higher than the mean squared error for Temperature control.

4. Conclusion

Finally, Based on the research, it can be concluded that the fuzzy controller has a robust performance, because using 5 different trials, the result is still within the acceptable range. In term of output, There are no big differences between Sugeno Methods and Mamdani methods. But Output for Mamdani methods tend to has ripples and oscillation. The average time for the system to get a stable humidity is 302 second. On the other hand, the average time for the system to get stable temperature is 342 second.The MSE for Humidity is 5,2929 and for the temperature is 1,7153. So, it can be concluded that Controlling humidity is more challenging because humidity is a parameter that easily changed during controlling the parameter of eggs incubator. Thus, further research should give more weight to humidity control. The next research should cover the possibility of using the real eggs that needed to be hatched, and calculate the success rate of the system.

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Table 4. Squared error after steady Temperature

No	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Set Point	Error	Squared Error
1	38,4	38,3	38,7	38,6	38,7	38,54	38	0,54	0,2916
2	38,8	38,6	38,8	39	39,1	38,86	38	0,86	0,7396
3	39,5	38,1	39	39,3	39,4	38,98	38	0,98	0,9604
4	39,8	39,2	39	39,5	39,7	39,38	38	1,38	1,9044
5	39,8	39,5	38,7	39,8	39,8	39,52	38	1,52	2,3104
6	39,9	39,7	38,5	39,9	39,9	39,58	38	1,58	2,4964
7	39,5	39,9	38,5	39,9	39,8	39,52	38	1,52	2,3104
8	39,5	39,9	38,7	39,8	39,7	39,52	38	1,52	2,3104
9	39,7	39,7	38,9	40	39,3	39,52	38	1,52	2,3104
10	39,9	39,9	39,2	39,9	39,1	39,6	38	1,6	2,56
11	39,7	39,9	39,4	39,9	39,1	39,6	38	1,6	2,56
12	39,4	39,4	39,7	39,9	39,3	39,54	38	1,54	2,3716
13	39,4	39,4	39,8	39,8	39,6	39,6	38	1,6	2,56
14	39,7	39,7	39,7	40	39,8	39,78	38	1,78	3,1684
15	38,2	39,6	38,9	39,8	39,9	39,28	38	1,28	1,6384
16	37,6	38,9	38,2	39,9	39,7	38,86	38	0,86	0,7396
17	37,5	38,9	38,8	39,1	39,5	38,76	38	0,76	0,5776
18	37,2	38,9	38,1	38,9	39,6	38,54	38	0,54	0,2916
19	37,2	38,5	38,9	39,4	39,5	38,7	38	0,7	0,49
				Mean Squared Error					1,71533

Table 5. Squared error After steady Humidity

No	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	Set Point	Error	Squared Error
1	54,9	58	60,8	57,1	54,9	57,14	58	-0,86	0,7396
2	56,9	56,7	54,9	60	55,9	56,88	58	-1,12	1,2544
3	56	55,6	54,8	57,8	57,8	56,4	58	-1,6	2,56
4	61,6	58,7	54,6	54,3	57,3	57,3	58	-0,7	0,49
5	57,2	54,9	57,5	54,6	57,1	56,26	58	-1,74	3,0276
6	56,1	55,2	56,8	55,7	58,2	56,4	58	-1,6	2,56
7	56,3	55,5	56,3	57,5	57,3	56,58	58	-1,42	2,0164
8	53,7	56,9	53,4	56,4	56,2	55,32	58	-2,68	7,1824
9	51,2	57,7	53,5	55,2	54,6	54,44	58	-3,56	12,674
10	47,7	57,8	55,3	54,9	56,2	54,38	58	-3,62	13,104
11	49,7	54,3	55,1	54,8	54	53,58	58	-4,42	19,536
12	52	56,8	56,2	55	57,6	55,52	58	-2,48	6,1504
13	54	55,8	55	55,9	52,5	54,64	58	-3,36	11,29
14	56,1	54,6	54,5	54,5	55,4	55,02	58	-2,89	8,8804
15	56,4	56,7	56,9	55,3	54,7	56	58	-2	4
16	55,9	55,9	55	56,3	54,4	55,5	58	-2,5	6,25
17	56,4	55,1	53,9	55	56,9	55,46	58	-2,54	6,4516
18	57,1	55,1	55,7	56,3	56,7	56,18	58	-1,82	3,3124
19	57,4	55,8	57,2	55,2	56,9	56,5	58	-1,5	2,25
20	56,9	56,4	57	56,6	55,2	56,42	58	-1,58	2,4964
21	57,3	55,3	57,3	56,8	55,3	56,4	58	-1,6	2,56
22	57,2	55,2	57,2	55,3	54,8	55,94	58	-2,06	4,2436
23	57,8	56	57,7	56,1	56,3	56,78	58	-1,22	1,4884
24	57,3	55,3	56,9	56,2	56,3	56,4	58	-1,6	2,56
				Mean Squared Error					5,2949

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