# Closed House Chicken Barn Climate Control Using Fuzzy Inference System

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***Abstract*—The hazardous gases in chicken barn such as Ammonia ($NH_3$) and hydrogen sulfide ($H_2S$) are the health threats to the farm animals and workers which influenced by climate changes. The chicken barn requires real-time control to maintain the barn climate and monitor hazardous gases. The outdated on-off and proportional control are not so efficient in energy saving and productivity. The solution to monitor environment of the chicken barn is using wireless electronic nose (e-nose) and Short Messaging System (SMS). The e-nose system is used for the barn's temperature and humidity data acquisition. The chicken barn climate control is utilizing fuzzy interface system. MATLAB software was used for the model which is developed based on Mamdani fuzzy interface system. The membership functions of fuzzy were generated, as well as the simulation and analysis of the climate control system. Results show that the performance of the fuzzy method can improve the system to control the barn's climate. This system also provides real-time alerts to farmers based on specific limit value for the climate. It makes it easier for farmers to follow up on-site or remotely control the environmental conditions in the barn by using the SMS system.**

***Index Terms*—Chicken Barn; Electronic Nose; Fuzzy Logic; SMS.**

## I. INTRODUCTION

Chicken has become one of the main sources of nutrition throughout Malaysia. They must be raised in comfort climate and good environment for optimum growth. Most farmers now use the closed house system for comfortable climate and good environment for optimum chicken growth [1]. The barn internal environment conditions such as temperature, humidity and air circulation must be monitored and controlled.

The use of a manual instrument to measure the barn climate is cost-effective, but the process must be repeated a few times which is time and energy consuming. Here, the closed house is usually equipped with a thermometer and on-off control for fans and cooling systems. The system is not controlled in real time which cannot respond to sudden changes in climate that can affect the animal health. The weather changes and the problem with electricity supply interruption could also cause chaos especially when this disturbs the cooling system that makes it not functioning properly.

A stable climate and good clean air in the barn will provide good environment condition for optimum animal growth [2]. The optimum animal body temperature depends on the barn climate and must be controlled [3]. Thus, temperature control is an important factor in the growth of chicken. The climate inside the barn is influenced by the external weather and the animal itself. Poor humidity can also cause respiratory disorder to the animal [4]. Table 1 shows the suitable range for barn's temperature which is from 26 to 29° C and for humidity from 50 to 70% [5]. The uncontrolled climate inside the barn could also contribute towards the spread of chicken diseases.

Table 1
Guidelines Poultry Performance at Difference Temperature

| Temp.(°C) | Animal activity |
|---|---|
| < 10 | Decrease in weight gain |
| 10 - 21 | Poor feed conversion ratio |
| 21 - 26 | Suitable environment for animal growth |
| 26 - 29 | Slight diminution of food consumption but adequate nutritional intake |
| 29 - 32 | Decrease in feeding and weight gain |
| 32 - 35 | Feeding and weight gain continues to decline |
| 35 - 38 | Decrease sharply in feeding but increase in drinking |
| > 38°C | Life threaten condition |

Usually, the closed house barn climate conditions are controlled using the exhaust fan and cooling pads as shown in Figure 1. The exhaust fan position and speed will control the air flow from cooling pads inside the barn. By improving the humidity, it will help decrease the temperature to the desired.

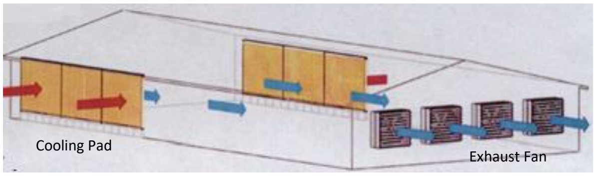


Figure 1: Closed house system with exhaust fan and cooler pad

## II. SYSTEM DESCRIPTION

### *A. Wireless Electronic Nose System*

Wireless e-nose has been used for monitoring applications, especially in environmental and agriculture [6]. Figure 2 shows the developed wireless e-nose system which consists of one main node and four e–noses or known as base nodes. The base nodes are used to acquired air sample, temperature, and humidity of the barn. The base nodes are placed at a certain location the barn and powered by a solar panel. For the climate control purpose, data are acquired only from temperature and humidity sensor.

Figure 2: The wireless electronic nose system

The main node shown in Figure 3 is equipped with a main 16-bit microcontroller (dsPIC33), a real-time clock (RTC) module, a Global System for Mobile (GSM) communication module [7], a Zigbee module from Nordic Inc. with 2.4GHz antenna and universal serial bus (USB) port. The main node functions as the main gateway between base nodes and SMS or web-based system via GPRS. The wireless nRF24L01+ Zigbee system is for the main node to communicate with the base nodes [8]. This device also has 16 ports for multipurpose analog and digital input or output. The digital input is used for checking the stability of the barn's electric supply. Meanwhile, the digital outputs are used to control the fan and cooling pads.

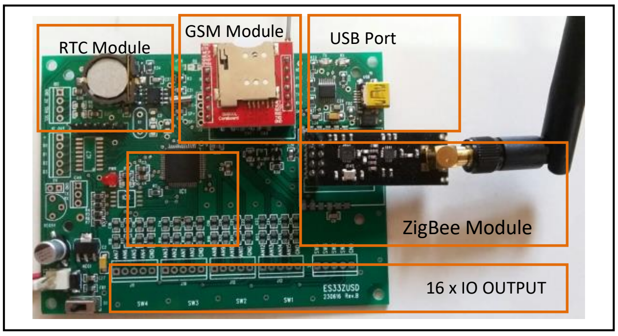


Figure 3: Main node with GSM module and Nordic Zigbee

### *B. Fuzzy Inference System*

Fuzzy Inference System (FIS) has been used widely in various fields such as data classification, automatic control, pattern recognition, decision analysis, time series prediction and robotics [9]. FIS which also known as a fuzzy expert system, fuzzy associative memory, fuzzy model and the fuzzy logic controller is the mapping process from given input(s) to output(s) using fuzzy logic. A fuzzy inference system outfits a nonlinear mapping from its crisp input to output space by proficient a number of fuzzy if-then rules. FIS basically structured with four main functional blocks as shown in Figure 4.

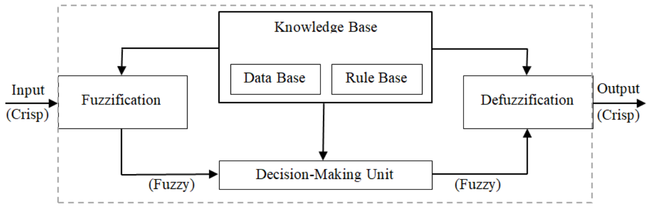


Figure 4: Structure of the Fuzzy Interface System

The knowledge base in this basic FIS structure developed by joining the rule base which consists of several fuzzy if-then rules and database which defines the membership function of the fuzzy sets used in fuzzy rules. A fuzzification performs an inputs transformation process from crisp into degrees of matches with linguistic value while a defuzzification performs fuzzy results into a crisp output. In decision-making block, FIS perform the inference operation on the pre-defined rule.

A fuzzy conditional statement or known as if-then rules can be expressed by:

$$\text{If x is A, Then y is B} \qquad (1)$$

where x and y are input and output linguistic variable while A and B are input and output label that has been set in membership function. Two types of fuzzy reasoning always being used in FIS are Mamdani and Sugeno type models. In this study, Mamdani type has been chosen due to defuzzification technique in generating an output which is widely accepted compared to Sugeno that uses a weighted average to compute the crisp output [10].

## III. METHODOLOGY

The sampling process was done at a chicken farm in Kedah, Malaysia. The barn climate will be monitored and controlled by measurement, calculation and adjustment process [11]. The samplings were done on day $9^{th}$, $18^{th}$, $27^{th}$ and $36^{th}$ of the chicken breeding period. Figure 5 shows the sketch of the chicken barn.

Each base node is placed in different locations with 50 meters distance between each other. Each node uses a 12 DC volt battery and equipped with a solar panel that has a capacity of 50 watts for charging purposes. The system is switched on for 36 days for chicken growth. All four base nodes will be in standby mode to reduce the instrument power consumption. The main node will be in standby mode even if the prescribed time interval has not been activated depending on the Real Time Clock (RTC). The main node will wake up if the time interval set has expired or there is an external interrupt like a trip signal from the sensor, interrupt input text from serial GSM, or an interrupt from Zigbee module.

Once the main node wakes up it will send a command to each base node to wake up and start the data acquisition. After the main node has received complete data from all the base nodes, it will send the data via GSM module to SMS mode and to the web-based via GPRS system. All data are stored in the web-based for analysis.

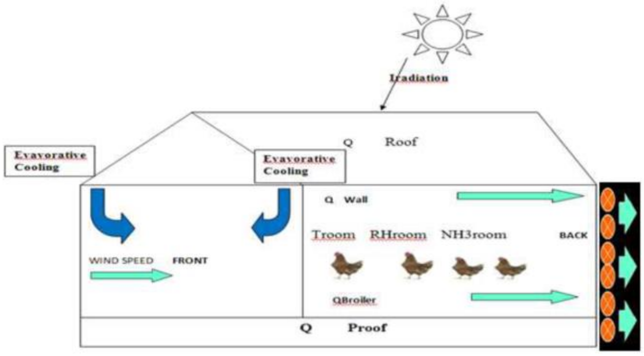


Figure 5: Sketch of the chicken barn

## IV. Results and Discussion

### *A. The SMS System*

Data collected by the main node that is obtained from the base nodes is the response of the sensor in real-time. Data are transmitted at the 2.4GHz signal with the speed of 250kbps in the barn and can also be done even with the distance range more than 50 meters. The GSM system also operates well even if the system is placed in the rural areas.

SMS which relates to respective sensor nodes will be received by users such as shown in Figure 6 when the message status request ‘Sts’ is sent to the system. From the received status, it can be analyzed that the temperature and humidity of each node are around 30ºC and relative humidity (RH) is around 63% which indicates that the rate is at a normal level. The state of electricity supply to the barn is also good which reflects the message “Power Supply OK”. Results of this test indicate that the system is capable of transmitting data acquired through SMS system when requested by the user. The system is also able to send an SMS alert to the user if the climate barn shows an unusual pattern and will activate the alarm system. Through SMS, users can also send a command to turn on or off the lamps, fans and the cooling system in the barn.

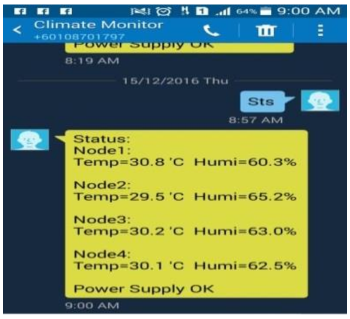


Figure 6: SMS status result

Figure 7 shows the data collected for 30 days from all four base nodes. Readings recorded are related to temperature and relative humidity of the air and taken from the site www.rmsens.com. Readings are taken for every one-hour interval. From the graph, it shows that the data obtained from each sensors nodes has successfully delivered to the web-based through the GPRS system.

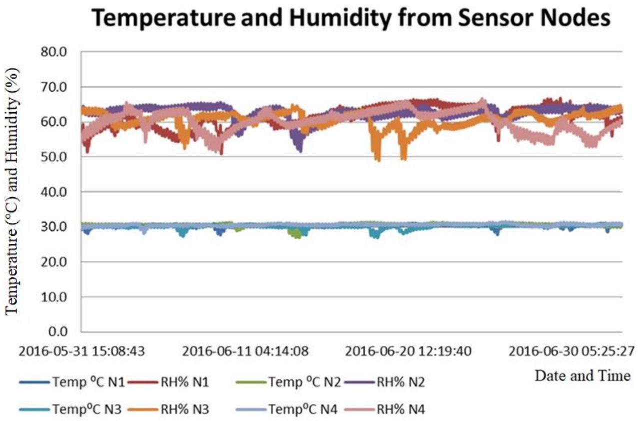


Figure 7: Temperature and humidity data

### *B. Development of Mamdani-type FIS*

To evaluate the closed house internal environmental conditions and control the exhaust fan speed, a Mamdani-type FIS as illustrated in Figure 8 is proposed, consists of two input variables: temperature and relative humidity. The system has one output that monitors and control exhaust fan motor speed.

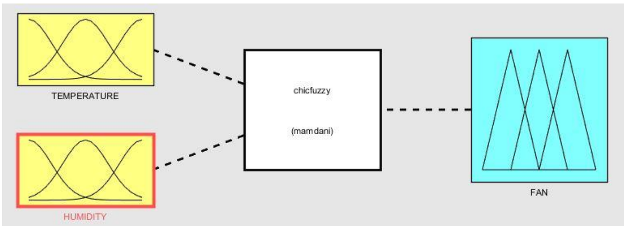


Figure 8: Mamdani-type FIS

The internal temperature range set until 45°C with four linguistic membership functions as per Malaysia temperature range while relative humidity was measured in percentage from 0% to 100% and divided into five membership function as illustrated in Figure 9.

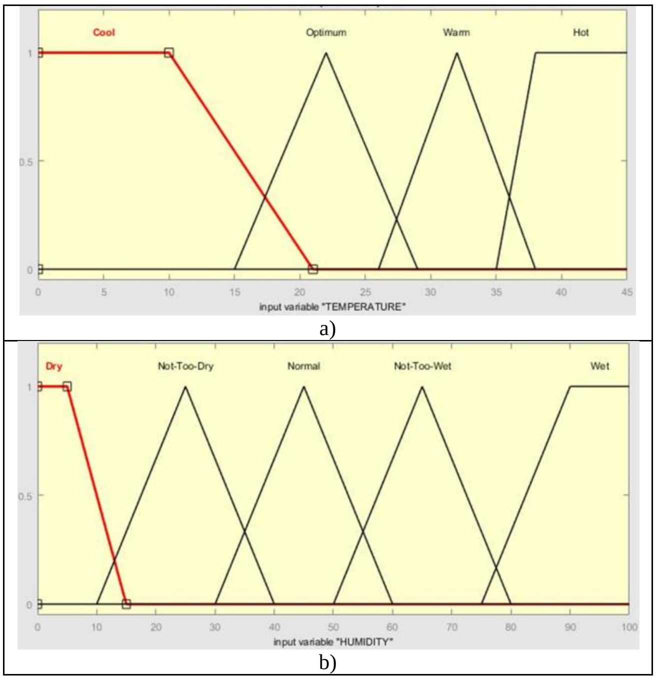


Figure 9: Input variable; a) Temperature with four membership function; b) Humidity with five membership function

The output generated from FIS in percentage from 0% to 100% as a feedback to control exhaust fan speed according to membership function set in Figure 10. Fan speed has been divided into five membership function in order to control the internal environment condition inside the barn.

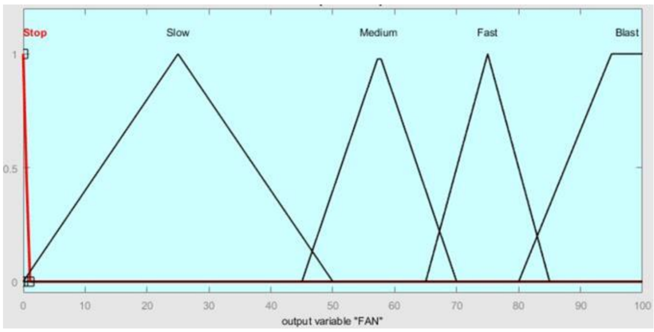


Figure 10: Output variable with five membership function for fan speed

Table 2
Fuzzy Inference Rules

| | | Humidity | | | | |
|---|---|---|---|---|---|---|
| | | Dry | Not-Too-Dry | Normal | Not-Too-Wet | Wet |
| Temperature | Cool | Stop | Stop | Stop | Stop | Stop |
| | Optimum | Stop | Stop | Slow | Slow | Medium |
| | Warm | Fast | Fast | Slow | Medium | Fast |
| | Hot | Fast | Fast | Blast | Blast | Blast |

The fuzzy inference rules for exhaust fan speed were designed manually by user-guided from previous research [12] and modified to suit with the weather in Malaysia. The fuzzy rules set from two input variables with four and five membership functions each that can generate up to 20 rules as shown in Table 2.

By using MATLAB Fuzzy Toolbox, the designed FIS model was simulated based on generated rules for inputs and output. Figure 11 illustrates the relationship between input and output in three-dimensional surface view.

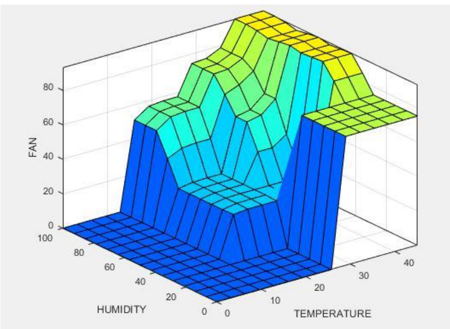


Figure 11: Surface view of input and output in Mamdani-type FIS

The fuzzy input variable of temperature (27°C) and RH (55%) are reflected to design the proposed chicken barn closed house system climate control based on standard room temperature in Malaysia. The signal value of temperature (27°C) overlaps with fuzzy membership function "Optimum" and "Warm", similarly, for the input value of humidity (55%), the corresponding crossing of fuzzy membership function are "Not Too Wet" and "Normal". The center of gravity defuzzification process takes in four input membership function which is in rule number 8, 9, 13 and 14th. This process then produces the defuzzified output signal, "Fan Speed" used to control the actuators of the control system as shown in Table 3. From here, it can be seen that the fan speed can be controlled accordingly to meet the desired climate.

Table 3
Singleton values for Fuzzy output

| Rules | Temperature | Humidity | Fan Speed |
|---|---|---|---|
| $R_0$(8) | Optimum (27) | Normal (55) | Slow(32.4) |
| $R_1$(9) | Optimum (27) | N.Too-Wet (55) | Slow(32.4) |
| $R_2$(13) | Warm (27) | Normal (55) | Slow(32.4) |
| $R_3$(14) | Warm (27) | N.Too-Wet (55) | Medium(32.4) |

Referring to data shows in Figure 7, there was not much change in the temperature reading due to control quality provide by fuzzy inference system. But, it still provide slightly high steady-state error for relative humidity from the desired humidity due to it vapor content easily affected by surrounding and the system works to maintain the steady state error not much than ±5%. Better control quality occurred by the accuracy of physical output parameter increased and this will cause an energy saving up to 12% in the system.

## V. CONCLUSION

The system has been successfully able to send SMS related data obtained from all nodes using GSM and GPRS module. The main node that receives data from each sensor nodes using Zigbee module is in accordance with a predetermined time interval. Communication between the sensors nodes and main node through Nordic Zigbee module is not affected even within 50 meters. Instructions received via SMS replies can perform tasks such as turn on the lighting, fan and cooling systems. By integrating Mamdani-type FIS, further control of the fan speed can be generated to have suitable climate inside the barn. This fuzzy based controller combines advantages of low power consumption and higher control quality compared to the conventional controller. Other advantages integrating with fuzzy inference system are a possibility to implement new rules into an existing system without modification and minimal works. Further work is to explore methods of controlling the system online using the application of Internet of Things (IoT) involving GPRS and web-based.

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## REFERENCES

[1] MOA, 2011. Expanding Livestock Industries. *National Agro Food Policy 2011-2020*, pp.60 – 64.

[2] Czarick, M., & Fairchild, B. D. (2012). Relative humidity... the best measure of overall poultry house air quality. Poultry Housing Tips, February. Available from: http://www.poultryventilation.com/tips/vol24/n2 [Accessed 09/08/2012].

[3] Fairchild, B. D. (2009). Environmental factors to control when brooding chicks. *The University of Georgia Cooperative Extension*, Bulletin 1287.

[4] Ammad-Uddin, M. Ayaz, M, Aggoune, E. H.& Sajjad, M, "Wireless sensor network: A complete solution for poultry farming," *ISTT 2014 - IEEE 2nd Int. Symp. Telecommun. Technol.*,(2015) pp. 321–325.

[5] Unit Unggas. (2006). Panduan penternakan ayam pedaging, *Ibupejabat Perkhidmatan Veterinar, Kem.Pertanian, Putrajaya*,Malaysia, Retrieved June 1, 2009 from: http://www.moa.gov.my/documents/10157.

[6] Satyanarayana, G.V. "Wireless Sensor Based Remote Monitoring System for Agriculture Using ZigBee and GPS," *Conf. Adv. Commun. Control Syst. 2013*, vol. 2013, no. Cac2s, 2013, pp. 110–114.

[7] Simc. W. S. Ltd, "SIM800 Series AT Command Manual," 2013.

[8] N. Semiconductor, "nRF24L01+ Datasheet," 2008.

[9] Ross, T., "Fuzzy Logic with Engineering Applications", McGraw Hill Publications, 2nd Edition, 1997.

[10] Blej, M & M. Azizi, M.,"Comparison of Mamdani-Type and Sugeno-Type Fuzzy Inference Systems for Fuzzy Real Time Scheduling," *Int. J. Appl. Eng. Res.*, vol. 11, no. 22, 2016, pp. 11071–11075.

[11] Nimmermark, S., & Gustafsson, G. (2005). Influence of temperature, humidity and ventilation rate on the release of odour and ammonia in a floor housing system for laying hens.

[12] CIGR-AgEng Conference Jun. 26–29, 2016, Aarhus, Denmark.