Design of an Intelligent Poultry Water Dispensing System Using Fuzzy Logic Control Technique

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Abstract

Manual method of feeding birds in the tropics makes poultry farming to be unnecessarily laborious and prohibitively costly. Over-involvement of humans in the feeding system of poultry leads to disease outbreak, stressful manual labour and malnutrition. These challenges instigate this research work by developing an intelligent fuzzy logic based system that mimics the roles of the poultry attendants in carrying out water dispensing at specified time intervals. The designed system has the ability to sense the level of the water in the trough and intelligently dispense water as water level decline in the trough in accordance with the variations in water level as birds consume the water. This system reduces workload of the poultry attendants, increases cost benefits and generates better return on investment in a deep litter poultry farming system.

Keywords: Microcontroller, Fuzzy Logic, AI, poultry, intelligent water dispensing, deep litter system.

1.0 INTRODUCTION

Poultry is the rearing of a collective group of birds such as turkeys, guinea fowls, quails, ostriches, geese and domestic chickens. These birds are kept for the primary purpose of meat and egg production. Other purpose includes pillow production through the industrial processing of the birds' feather and production of confectioneries (Oluyemi and Robert, 1986). Poultry industry is one of the main sources of protein for human consumption which makes its primary production to be consequential. In order to improve the production in poultry management, poultry nutrition needs to be effectively managed. Effectiveness in the poultry production could be attributed to an effective management of the birds' nutrition. Whereas, feeding of birds is driven manually in the tropics (Anne *et al.*, 2001).

This manual pattern of feeding is a challenge as it aggravates the cost of production in the poultry industry. Feeds claim 75% of the cost of production in poultry management (Odunsi, 2006). The poor method of feeding causes wastage of feed, improper administration of feed, unfavorable weather in the poultry, stressful manual labour, disease outbreak, fatigue and makes the cost of production to be high capital intensive. These measures discourage people from venturing into poultry business. In addition to this, some jobs interfere with feeding, like picking of eggs laid by the matured layers, medication of the sick birds and overhauling of the litter material. The pressure that these farmers experience increases as the number of birds increases (Sainsbury, 2000). The challenges highlighted above brought about the intervention of a technology that could address and curb the flaws in the above stated problem in system of feeding poultry in the tropics. This includes the development of feed dispensing system that could supply water to birds at appropriate time intervals. A system of this nature was proposed in 2004 by Adedinsewo.

The system depends on a computer system to operate. Furthermore, it was not obstruction sensitive. Also in 2006, Omosebi developed a related system which could only move in horizontal and vertical direction axis (its operation depends on its position). These proposed systems by (Omosebi, 2006 and Adedinsewo, 2004) are dependents on control program written on the computer system. However, control program delivers operation to the system through the parallel port. Besides, cross talk do have defect on the computer parallel port. Moreover, declination in the level of performance in long distance parallel transmission is attributed to the cross talk (Arulogun et *al*, 2010).

Arulogun et *al* 2010 developed a system that could address and solve some of the limitations in the existing literatures. This development was achieved with the aid of microcontroller as the process controller, instead of the program written on the computer system. The principle of operation of the model proposed in Arulogun et *al* (2010) is not hygienic due to the fact that it dispenses feed on the floor as it operates. Besides, uniform feeding of large number of bird could not be achieved with the system. However, it could only cater for solid feed (grains), thereby leaving liquid feed (water) to be dispensed manually for the birds, which could still be attributed to manual labour in the feeding system of birds. Therefore, there is the need to develop a model that would be capable of dispensing both the liquid feed (water) and solid feed (grains) simultaneously into the respective feeding trough in a hygienic manner. A control methodology called fuzzy logic is adopted to achieve such system. Fuzzy logic mimics the human intelligence of making decision, taking action and adapting to changes in the environment where they dwell.

This research work therefore, present an intelligent poultry water dispensing system capable of sensing the water level status in the trough and dispense water as the water level drops, i.e. ensuring that there is never water shortage in the trough. The proposed model will also ensure that the recommended amount of water is given to the birds. The system is stationary as it dispenses water into the appropriate trough. It would be effective in a deep litter poultry farming system.

2. FUZZY LOGIC

Fuzzy logic is a control methodology that possesses the ability to mimic human intelligence. It is capable of monitoring the relationship between the input and the output of real life systems. Fuzzy logic is adopted in this study because it is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or destroyed. Also, it can be modified and tweaked easily to improve or drastically alter system performance. The output control is a smooth control function despite a wide range of input variations (Steven, 1991).

2.1 Fuzzy Logic Controller (FLC)

Fuzzy Logic Controller (FLC) constitutes a simple, rule-based IF X AND Y THEN Z statement to control the operation of real life systems. FLC is an approach in solving control problems rather than attempting to model a system mathematically (Hill et al., 2007). The FLC model is empirical as it is based on a verifiable observation rather than pure logic and theory. It also makes use of the operator's experience rather than their technical understanding of the system. For instance, rather than dealing with water level control in terms such as "AF =8.5Liter", "F =10Liter", or "AE =3Liter","E =0.5liter", in FLC terms like IF (water level is low) AND (water level is getting lower) THEN (dispense water) are used. In spite of the vagueness of these statements, yet they are very descriptive of the instruction to be executed. FLC is capable of mimicking this type of behaviour at a very high rate. The block diagram depicted in figure 1.0 shows step by step involve in designing FLC (Chuen Chien, 1990).

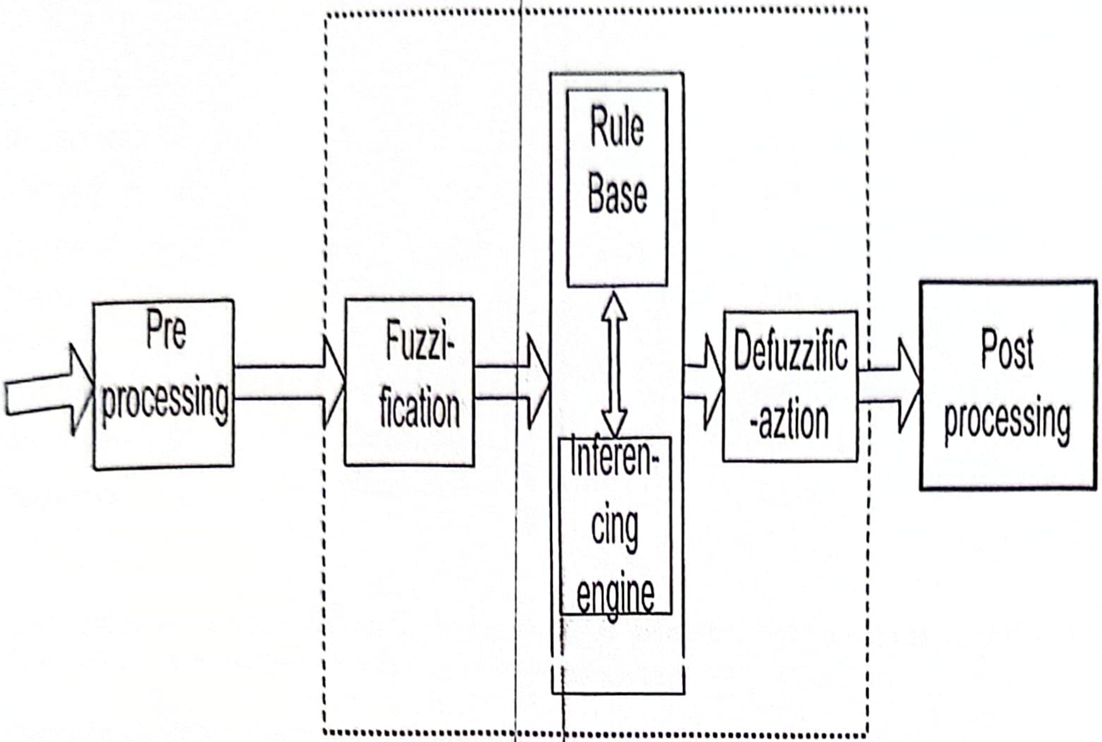

Figure 1: Fuzzy logic controller design

Preprocessing: This is the first step in designing a fuzzy logic controller. It basically involves the method of defining the nature of the inputs of real life systems. Example of preprocessing are: Quantization in connection with sampling, normalization or on to a particular standard range filtering in order to remove noise, averaging to obtain long term or short term tendencies, a combination of several measurements to obtain key indicators and differentiation ant integration or their discrete equivalencies.

Fuzzification: Fuzzification involves the conversion of the input defined by preprocessing to degrees of membership. It makes the input data to correspond with the rule base conditions. The Fuzzification block matches the input data with the condition of the rules to determine how well the condition of each rule matches that particular input circumstances.

Rule Base: This is the development of the rule-based structure of FL in order to break the control problem down into series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions for example: If j is P then k is Q where P is a set of conditions that have to be satisfied and Q is a set of consequences that can be inferred. Fuzzy operators are used to combine more than one input in rules that has multiple parts. One of the rule formats of a fuzzy set is shown below:

Error	Change in Error	Output
Negative	Positive	Zero
Negative	Zero	NM
Negative	Negative	NB
Zero	Positive	PM
Zero	Zero	Zero
Zero	Negative	NM
Positive	Positive	PB
Positive	Zero	PM
Positive	Negative	Zero

The two left columns represent all the input variables, while the right most represents the output. This is accurate for a user who needs a quick over view of the rule base.

Membership function: The membership function is a graphical representation of the magnitude of participation of each input. At this stage FL membership functions that define the meaning (values) of Input/output terms used in the rules are generated.

Inferencing engine: The purpose of inferencing is to determine the firing strength of each rule developed in step three. The logical products for each rule must be combined or inferred using max-min'd, maxdot'd, averaged or root-sum-squared method before being passed on to the defuzzification process for crisp output generation.

Defuzzification: Defuzzification involves the conversion of the fuzzy set result to a number that can be sent to the process as a control signal. Defuzzification process depends on the type of fuzzy data that is been processed which can involve approximation of linguistic variable or an arithmetic method. Defuzzification process involves the task to find one single crisp value that summaries the fuzzy se. some of the methods are, centroid, bisection, largest of maximum, smallest of maximum, middle of maximum and weight average.

Post processing: This is the scaling of the output to engineering unit. In this study volume of water will be measured in centiliter.

3.0 MATERIAL AND METHOD

The system consists of a reservoir which is the receptacle that contains the water to be dispensed into the drinking trough. A sensor is mounted inside the reservoir to monitor the state of the water level. The water will flow via a channel that leads to the base of the drinking trough for the birds to drink. Along this channel is a DC water pump that will control the flow of water. The flow controls occur with respect to the signal output of the sensor element placed at the base of the trough. DC water pump operate according to the programs developed with the aid of Fuzzy rules. However, implementation of the program is done by the MCU.

The overall system is divided into sub-units that synchronize. The subunits are the controller, the DC motor, the sensor interfacing unit, power supply unit, dispensing unit and sensor unit. The overall system block diagram is depicted in the figure 2.0. The power unit supply electrical energy to every unit that requires power while the interfacing unit allows the interaction between the system and the sensor unit.

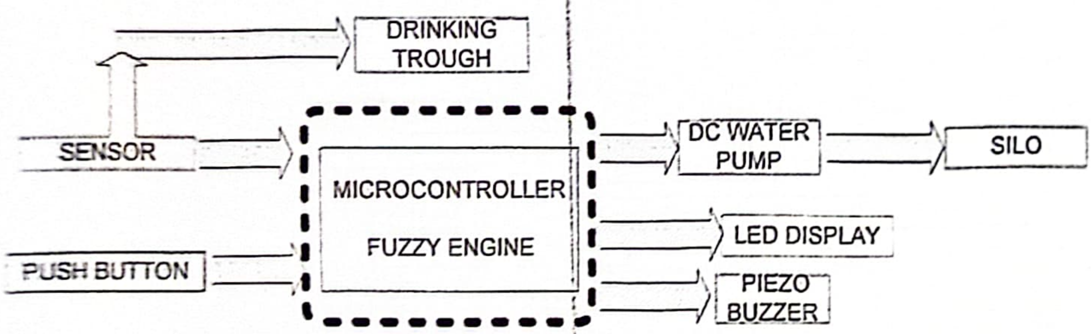

Figure 2: OVERALL POULTRY WATER DISPENSING SYSTEM BLOCK DIAGRAM

3.1 Hardware design considerations

The MCU: The formal role of the PIC 16F877A micro controller is to provide inexpensive programmable logic control and interfacing with external devices. The microcontroller embeds the Fuzzy Logic System after designing the system. PIC 16F877A microcontroller is a RISC based microcontroller with 40 pins and many internal peripherals and modules. It features 256byte of EEPROM data memory, self programming, an ICD, 2 comparator, 8 channels of 10-bit Analogue to Digital (A/D) converter and 200ns instruction execution (Janice *et al.*, 2003).

The Input and Output Interface Unit: The input interface consists of the sensors while the output interface includes the piezo buzzer and the LEDs.

The Sensor: This is a sensing device that monitors the relationship between the input and output of the system. It basically consists of a photodiode which uses an infrared emitted diode combined with an infrared phototransistor to detect that reflect infrared signal. Phototransistor is a semiconductor light sensor formed from a basic transistor with transparent cover that can provide much better sensitivity than photodiode.

LED (Light Emitting Diode): The function of the LED is to display the state of the water level as it increases or reduce in the silo vice versa. It is interfaced with the microcontroller. The role of the LEDs would allow a bare illiterate to be able to operate the system.

Piezio buzzer: The function of the piezo buzzer to notify the emptiness and fullness of the silo by beeping.

Motor circuit: This consists of an interface circuit that enables the MCU to control the DC water pump. The proposed circuit diagram of the study is shown in figure3.

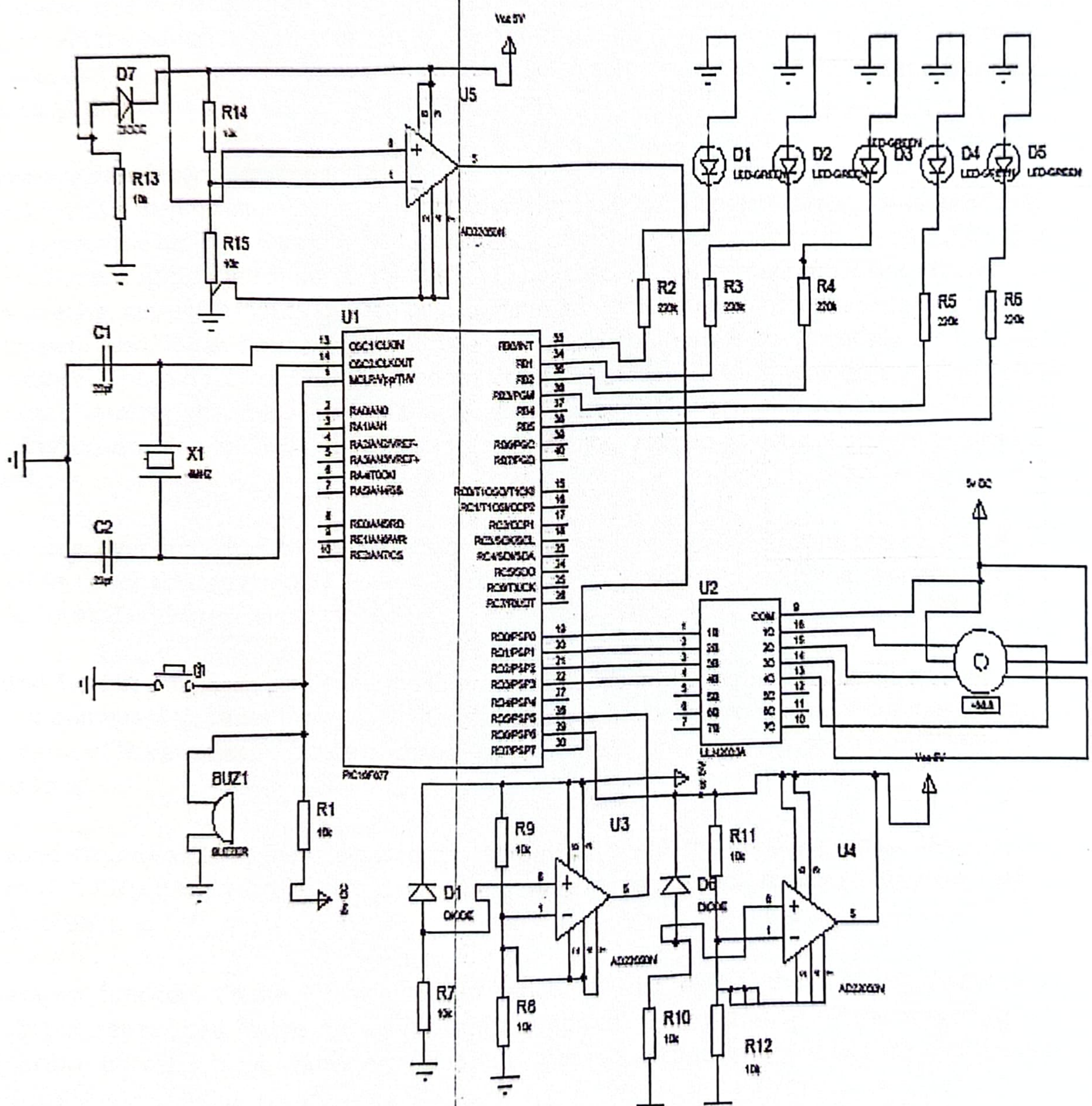

Figure 3: System Circiut Diagram

Mechanical unit: This involves the fabrication of the water silo, the poultry water trough and the silo stand. Silo is a receptacle for storing the water to be dispensed while trough is a round narrow open container that holds water for birds to drink. Both the trough and the silo will be made up of plastic materials. Water flows to the trough when the MCU sends appropriate signal to the DC water pump through the motor interface circuit. The sensor in the trough also determines the amount of water to be released by the water pump (sensing when the water level drops and when it is low vice versa). The reason for choosing the DC water pump is because of its effective ability to control the flow of water at a specified rate via a channel. Fabrication of the silo stand would be done with the aid of some length of 16mm iron rod in order to hold the water reservoir.

Power pack: This is made up of the transformer, wien bridge diode, capacitors, positive voltage regolator and the power LED. The purpose of the power pack is to step down the 220V AC source to 5V DC source that is required to power the MCU. Also to step-down the 12V DC voltage from a dc battery to 5V DC incase of power failure (Theraja., 2002).

3.2 Software design considerations

This will involve the implementation of Fuzzy Logic Control. Fuzzy Logic is a control methodology that possesses the ability to mimic human intelligence of making decision in an imprecise and vague scenario. Fuzzy Logic is used in designing this study because it is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. Also, it can be modified and tweaked easily to improve or drastically alter system performance. The output control is a smooth control function despite a wide range of input variations. However, this study involves the design of Fuzzy Logic Controller for the poultry water dispensing system. The following are the steps in designing fuzzy logic control system propose in this study:

Control objectives and criteria: This consists of defining what is to be controlled, the method to be adopted in controlling system and what kind of response is expected from the system. Also the possible (probable) system failure modes

Input and Output relationships: Define the interaction between the input and output and choose a minimum number of variables for input to the FL engine (typically error and rate-of-change-of-error). The purpose of the error and the rate of change of error are to prevent the system from a long-term overshooting.

Rule-based structure: Using the rule-based structure of FL, break the control problem down into a series of IF X AND Y THEN Z rules that define the desired system output response for given system input conditions.

Membership function: Create FL membership functions that define the meaning (values) of Input/output terms used in the rules. This is the graphical representation of the magnitude of participation of each input. Both error-dot and the significant error would be individually represented.

Testing and Evaluation: Test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

The output responses for the system are to dispense water, No change and withhold water. These ranges are stated clearly below:
"N" = "negative" error or error-dot input level
"Z" = "zero" error or error-dot input level
"P" = "positive" error or error-dot input level
"D" = "Dispense" output response
"NC" = "No Change" to current output
"W" = "Withhold" output response
The minimum numbers of possible input product combinations for the intelligent feed dispenser from figure 4 have been chosen to be error, rate of change of error (error- dot).

C. Fuzzy rule formulation
From step A and step B, input and definitions are:
INPUT#1: ("Error", positive (P), zero (Z), negative (N))
INPUT#2: ("Error-dot", positive (P), zero (Z), negative (N))

Conclusion: ("Output", Dispense (D), No Change (-), withhold (W))
INPUT#1 System Status
Error = CMD - Feedback
P = Too Empty
Z = Just right
N = Too Full
INPUT#2 System Status
Error-dot = d(Error)/dt
P = Getting empty
Z = Not changing
N = Getting too full

OUTPUT Conclusion & System Response
Output "D" = Dispense water
Output "-" = Don't change anything
Output "W" = withhold water

Division of control problem into IF X THEN Z rules
The rule structure for the purpose of this study is thus:
IF CMD-WL=N AND d(CMD-WL)/dt=N THEN output=W
IF CMD-WL=Z AND d(CMD-WL)/dt=N THEN output=W
IF CMD-WL=P AND d(CMD-WL)/dt=N THEN output=D
IF CMD-WL=N AND d(CMD-WL)/dt=ZTHEN output=W
IF CMD-WL=Z AND d(CMD-WL)/dt=ZTHEN output=NC
IF CMD-WL=P AND d(CMD-WL)/dt=ZTHEN output=D
IF CMD-WL=N AND d(CMD-WL)/dt=PTHEN output=W
IF CMD-WL=Z AND d(CMD-WL)/dt=PTHEN output=D
IF CMD-WL=P AND d(CMD-WL)/dt=PTHEN output=D

The rule matrix for the rule structure is shown next.

1 W	2 W	3 D
4 W	5 NC	6 D
7 W	8 D	9 D

D. Formulation of Membership Function:

The triangular membership functions from the rule structure of the poultry water dispensing system are shown in figure 5 and figure 6 for both error and rate of change of error input variables.

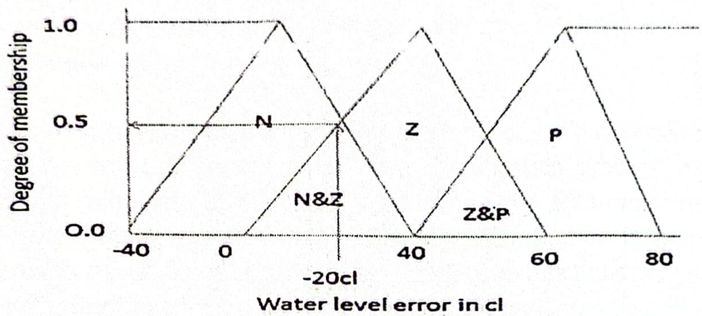

Figure 5: Error input membership function

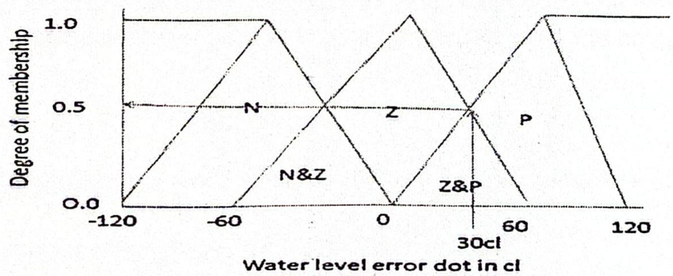

Figure 6: Error-dot input membership function

E. System Data Summary

INPUT DEGREE OF MEMBERSHIP:

"error" = -20cl: "negative" = 0.5 and "zero" = 0.5

"error-dot" = +30cl: "zero" = 0.5 and "positive" = 0.5

Now referring back to the rules, plug in the membership function weights from above. "Error" selects rules 1,2,4,5,7,8 while "error-dot" selects rules 4 through 9. "Error" and "error-dot" for all rules are combined to a logical product (LP or AND, that is the minimum of either term). Of the nine rules selected, only four (rules 4,5,7,8) fire or have non-zero results. This leaves fuzzy output response magnitudes for only "withhold" and "No_Change" which must be inferred, combined, and defuzzified to return the actual crisp output.

The following definitions applies in the rule list below: (e)=error, (er)=error-dot:
If (e < 0) AND (er < 0) then Withhold 0.5 & 0.0 = 0.0
If (e = 0) AND (er < 0) then Dispense 0.5 & 0.0 = 0.0
If (e > 0) AND (er < 0) then Dispense 0.0 & 0.0 = 0.0
If (e < 0) AND (er = 0) then Withhold 0.5 & 0.5 = 0.5
If (e = 0) AND (er = 0) then No_Chng 0.5 & 0.5 = 0.5
If (e > 0) AND (er = 0) then Dispense 0.0 & 0.5 = 0.0
If (e < 0) AND (er > 0) then Withhold 0.5 & 0.5 = 0.5
If (e = 0) AND (er > 0) then Withhold 0.5 & 0.5 = 0.5
If (e > 0) AND (er > 0) then Dispense 0.0 & 0 = 0.0

F. Inferencing

This involves determining the firing strength of each rule of the system. By comparing the membership function and the rule matrix in above design only rule 4,5,7 and 8 fire at 50% while rule1,2,3,6 and 9 do not fire at all(0%).

The logical products for each rule will be combined or inferred (max-min'd, maxdot'd, averaged, root-sum-squared, etc.) before being passed on to the defuzzification process for crisp output generation. The horizontal coordinate of the "fuzzy centroid" of the area under that function is taken as the output. In this study, the ROOT-SUM-SQUARE (RSS) method is adopted. The RSS method combines the effects of all applicable rules, scales the functions at their respective magnitudes, and computes the "fuzzy" centroid of the composite area.

G. Defuzzification: This is the conversion of the fuzzy set result to a number that can be sent to the process as a control signal. From the error membership function in figure 4 and 5, an error of -20cl and an error-dot of +30cl select regions of the "negative" and "zero" output membership functions. The respective output membership function strengths (range: 0-1) from the possible rules (R1-R9) are:

Therefore;
"Negative" or Dispensing Ouput = (R1^2 + R4^2 + R7^2 + R8^2) = (0.00^2 + 0.50^2 + 0.50^2 + 0.50^2)^.5 = 0.866
"Zero" or No Change Output = (R5^2)^.5 = (0.50^2)^.5 = 0.500
"Positive" or Withhold Output = (R2^2 + R3^2 + R6^2 + R9^2) = (0.00^2 + 0.00^2 + 0.00^2 + 0.00^2)^.5 = 0.000

Fuzzy logic centroid equation for the water dispensing system is given below:
Formula: OUTPUT = (neg_center * neg_strength + zero_center * zero_strength + pos_center * pos_strength) / (neg_strength + zero_strength + pos_strength)
(-100 * 0.866 + 0 * 0.500 + 100 * 0.000) / (0.866 + 0.500 + 0.000) = 63.4%

4.0 CONCLUSION

In this study effort towards the improvement in performance of existing feed dispensing systems was made. The study has presented an intelligent water dispensing system using fuzzy logic control method. This anticipated system after the final development of the proposed designed shall be capable of sensing the water level inside the drinking trough to dispense more water as the level drops, for reduced intensive manual labour experienced in the poultry farming with corresponding increase in cost benefits, high profit yield and making feeding to be hygienic in poultry farms.

5.0 FUTURE WORKS

The fuzzy logic controller for the dispensing system would be improved upon to accommodate both the feed and water level prior to implementation and development on appropriate sensors and microcontroller systems for improved cost benefits and minimal human intervention in deep litter poultry feeding system.

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