Fuzzy Logic Control-Based Automatic Cat Feeding System

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***Abstract*—Automatic cat feeder based on fuzzy logic control is designed to maintain healthy nutrition in cats so that they are maintained and it can provide convenience for cat owners. Furthermore, the sensor is used as the input value in order to obtain the output value after processing by fuzzy. The resulting output value is based on logic. Meanwhile, the value of the cat's food portion is based on the calculation of the dose taking into account the cat's weight and condition. In this study, the fuzzy type used was the Mamdani method with two inputs and one output. The volume of cat food would be detected by using an ultrasonic sensor by utilizing reflected waves while the weight of cat food would be detected by using a weight sensor (load cell). Moreover, the output obtained is the time the servo motor valve opens to remove the feed into the feeder. The results of this study are obtained from hardware testing, software testing, and mathematical calculations based on the centroid method. Hardware testing uses Arduino Uno while software design and testing uses tool box.**

Keywords—***Cat feeder, fuzzy logic control, Ultrasonic.***

I. INTRODUCTION

Cats are one of the animals that are often kept as pets by humans and have become part of human life [1]. Cats need a lot of care to ensure their well-being and to maintain their health. One of the treatments for cats is to maintain their diet. Feeding cats regularly is very important to maintain a balance of nutrition and nutrition in cats [2]. If the portion given is too little or too much, it will result in the cat not having a balanced nutrition and will have an impact on his health [3].

Considering these problems, Fuzzy Logic Control (FLC) can be a solution for giving the right portion of the feed to cats so that the portion shown is not excessive and remains consistent. FLC provides tolerance values based on human logic. FLC can represent truth values in the range 0 to 1 [4][5][6][7]. In its implementation, FLC requires input from sensors to carry out further processing. Sensors that can be used in the case of automatic cat feeding are the ultrasonic sensor HC-SR04 and the weight sensor (load cell).

The ultrasonic sensor HC-SR04 is used as an input value for detecting the availability of feed in the cat's feeding area. The ultrasonic sensor HC-SR04 can measure distance through the speed of wave propagation by making use of the reflection and reception of waves [8]. Meanwhile, the weight sensor (load cell) is used to detect the weight of the feed contained in the cat's feeding area. Servo motor is used as an actuator in this research. The resulting output is the time the servo motor opens the valve. The length of time the valve is open will determine the amount of feed removed.

Several researches on the automation of feeding have been carried out. Research conducted by Nisa Hanum Harani, et al [9] developing a hybrid feeding system. The system he developed combines automatic feeding and remotely controlled manual feeding. The system used uses FLC with Arduino Uno controller. However, in this study, the dose given to feed the cat was still based on the cat's weight.

Research conducted by Nur Izzatul, et al [10] more focus on adding a food position tracker feature. The controller used is Arduino Uno with notification output regarding the state of the cat's feeding tray (full and exhausted) but no weight sensor is used to provide a more accurate value.

Meanwhile Soumallya Koley, et al [11] develop a feeding system that focuses on feeding schedules. However, the portion given is not calculated based on the needs and weight of the cat. The owner can set the time and amount of food via the keyboard to supply food depending on the instantaneous weight of the food in the bowl.

Meanwhile Akbar Riansyah, et al [12] researching about feeding fish by using fish body weight as a reference for feeding portions with aquarium monitoring. Feeding is given in doses. Android application based monitoring.

This paper discusses the FLC-based control system for cat feeding by the Mamdani method. The system developed not only takes into account the output based on the cat's weight, but also takes into account the cat's energy needs in one day. So in addition to feeding will be given on time, feeding will also be carried out taking into account the cat's daily calorie needs. So that in addition to automatic feeding, pet cats will also get food with appropriate portions and doses to minimize nutritional deficiencies or excesses.

II. SYSTEM MODEL

A. Block Diagram

There are three stages of the system in this automatic cat feeding, namely input, process, and output. The input in this research is an ultrasonic sensor and a weight sensor (load cell), the process using fuzzy logic method, and the output is a servo motor as shown in Fig. 1.

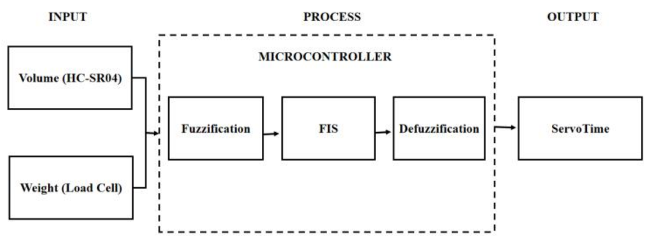

Fig. 1 Block diagram system.

The following is an explanation of the block diagram system Fig. 1 :

- The input section consists of an ultrasonic distance sensor HC-SR04 and a weight sensor sensor (load cell). The number of ultrasonic sensors used is one to detect the feed in the cat's feeder and one weight sensor to detect the weight of the feed in the cat's feeder.
- The process part will be carried out by the Arduino Uno microcontroller. Input from the sensor will be processed by the microcontroller to control using FLC.
- The output part is the final result of processing. The output is the length of time the servo is open in the cat feed storage area that adjusts to the need for food portions (grams).

B. Hardware Design

The manufacture of the Automatic Cat Feeding System requires several supporting materials, namely the Table I. Needs include all components supporting the tool. Prior to use, each sensor is tested first

TABLE I. COMPONENT.

No	Component Name	Total
1	Arduino Uno	1
2	Ultrasonic HC-SR04	1
3	*Load cell*	1
4	Jumper	11
5	Baterai 5 Volt	1
6	Servo DC	1

C. Feed Dose

Feeding is based on Resting Energy Requirement (RER) and Daily Energy Requirement (DER) in cats who are the object of research [13]. The cat that became the object was categorized as a Persian cat with a weight of 4.6 kg in a condition not yet sterile.

1) RER

RER is the total energy needed by animals in a resting state for 24 hours or one day, obtained using equation (1) is [13]:

$$\text{RER (Kcal)} = 70 \text{ x } (\text{KgBB})^{0.75} \quad (1)$$

$$= 70 \text{ x } (4.6)^{0.75}$$

$$= 219.870 \text{ Kcal}$$

2) DER

DER or the daily requirement of a cat can be calculated by multiplying the RER depending on the condition of the cat as in Table II, namely:

TABLE II. DER INFORMATION.

Information	Description
Already sterile	1.2-1.4 x RER
Not sterile	1.4-1.6 x RER
Prone to obesity	1.0 x RER
Weight loss	0.8 x RER
Weight gain	1.2-1.8 x RER
Senior	1.1-1.4 x RER

The cat that is the object of the study has an unsterile condition and is an active cat, then the DER value according to equation (2) is [13]:

$$\text{DER} = 1.6 \text{ x RER} \quad (2)$$

$$= 1.6 \text{ x } 219.870$$

$$= 351.792 \text{ Kcal}$$

3) Feed Portion

This study uses the cat food brand Proplan with the ME (Energy Metabolism) value listed on the packaging as 3.9 Kcal/gr. Then the correct portion of the feed to be given to the cat for 1 day according to the energy required by the cat according to equation (3) is [13]:

$$\text{Feed Portion} = \text{DER : ME} \quad (3)$$

$$= 351.792 \text{ Kcal : } 3.9 \text{ Kcal/gram}$$

$$= 90.20 \text{ gram}$$

Feeding is 3 times a day, so the portion for one feeding is 30 grams.

D. Control System Design

The design of the FLC using the Mamdani method is carried out on the toolbox. There are two input variables, namely volume (HC-SR04) and weight (load cell). For the output, there is 1 variable namely ServoTime (Servo Motor) as shown in Fig. 2.

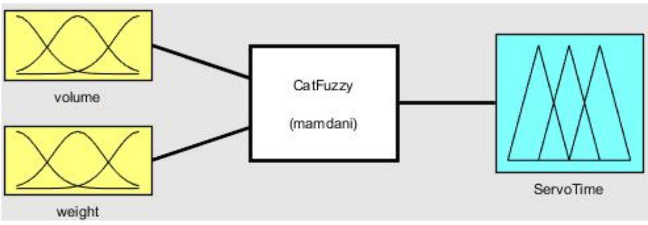

Fig. 2 Fuzzy logic Mamdani design.

At each input and output, a membership function is made with a limit that is adjusted to the testing data and needs. The attached equations in equation (4) to equation (13) are:

1) μ_{Volume}

The input volume is divided into three membership functions, namely Empty (μ_{Ep}), Middle (μ_{Md}), and Full (μ_{Fu}). The value of the equation contained in the membership function is based on the gradient equation on the trapezoidal curve.

$$\mu_{Ep} = \begin{cases} 1, x \leq 20 \\ \frac{50 - x}{30}, 20 \leq x \leq 50 \\ 0, x \geq 50 \end{cases} \quad (4)$$

$$\mu_{Md} = \begin{cases} \frac{x - 20}{30}, 20 \leq x \leq 50 \\ 1, 50 \leq x \leq 70 \\ \frac{100 - x}{30}, 70 \leq x \leq 100 \end{cases} \quad (5)$$

$$\mu_{Fu} = \begin{cases} \frac{x - 70}{30}, 70 \leq x \leq 100 \\ 1, x \geq 100 \end{cases} \quad (6)$$

The maximum limit in the above equation is obtained from the results of 10 experiments. The ultrasonic sensor in reading the volume of feed in the cat's feeder in full condition.

2) μ_{Weight}

The input weight is divided into three membership functions, namely VeryLight (μ_{VeL}), Light (μ_{Lg}), and Heavy (μ_{Hv}). The value of the equation contained in the membership function is based on the gradient equation on the trapezoidal curve.

$$\mu_{VeL} = \begin{cases} 1, x \leq 6 \\ \frac{12 - x}{6}, 6 \leq x \leq 12 \\ 0, x \geq 12 \end{cases} \quad (7)$$

$$\mu_{Lg} = \begin{cases} \frac{x - 6}{6}, 6 \leq x \leq 12 \\ 1, 12 \leq x \leq 18 \\ \frac{24 - x}{6}, 18 \leq x \leq 24 \end{cases} \quad (8)$$

$$\mu_{Hv} = \begin{cases} \frac{x - 18}{6}, 18 \leq x \leq 24 \\ 1, x \geq 24 \end{cases} \quad (9)$$

The above equation is obtained from the calculation of the portion of feed in one day for the cat who is the object, namely the maximum reference limit is 30 grams for one feeding.

3) ServoTime

The ServoTime output is divided into three membership functions, namely Fast (μ_{Fs}), Awhile (μ_{Aw}), and Long (μ_{Fs}). The value of the equation contained in the membership function is based on the gradient equation on the trapezoidal curve.

$$\mu_{Fs} = \begin{cases} 1, x \leq 2 \\ \frac{3 - x}{1}, 2 \leq x \leq 3 \\ 0, x \geq 3 \end{cases} \quad (10)$$

$$\mu_{Aw} = \begin{cases} \frac{x - 2}{1}, 2 \leq x \leq 3 \\ 1, 3 \leq x \leq 5 \\ \frac{6 - x}{1}, 5 \leq x \leq 6 \end{cases} \quad (11)$$

$$\mu_{Lg} = \begin{cases} \frac{x - 5}{1}, 5 \leq x \leq 6 \\ 1, x \geq 6 \end{cases} \quad (12)$$

The maximum limit in the above equation is obtained from the results of 10 experiments for the servo motor to open and remove feed as much as 30 grams. To process the received sensor input, 9 rules are used with logical considerations as in Table III.

TABLE III. RULES.

Rules	Input		Output
	Volume	**Weight**	**ServoTime**
R1	Empty	VeryLight	Long
R2	Empty	Light	Fast
R3	Empty	Heavy	Closed
R4	Middle	VeryLight	Awhile
R5	Middle	Light	Awhile
R6	Middle	Heavy	Fast
R7	Full	VeryLight	Fast
R8	Full	Light	Fast
R9	Full	Heavy	Closed

III. RESULT AND ANALYSIS

This research went through several stages of testing. That stages is on hardware, software, and manual calculations as well as making comparisons. one of the case studies was taken with the input volume value of 30 cm^3 and weight of 10 grams.

A. Hardware Testing

The hardware test results give a ServoTime output of 4.00 seconds as shown in Fig. 3 hardware testing is done by looking at the results of the input sensor readings to produce output that can be seen on the Serial Monitor.

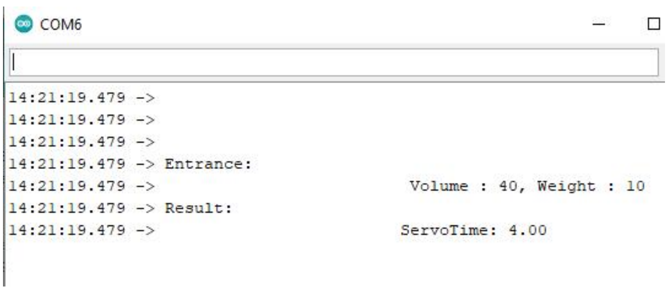

Fig. 3 Output of hardware testing.

The picture above is the result of the Arduino UNO test and the results of the HC-SR04 ultrasonic sensor reading and load cell sensor. The results show the detected volume is 40 cm^3 and the detected weight is 10 grams. The time required for the servo to open is 4 seconds. Within 4 seconds, the detected feed in the cat's feeding place was 10 grams. Case examples are taken to provide convenience in making comparisons between the results of hardware system testing, simulation test results, and manual calculation results. In comparison, the test results from the simulation will be the reference value because it is considered the most appropriate value.

B. Software Testing

The results of the software test give a ServoTime output of 4 seconds as shown in Fig. 4.

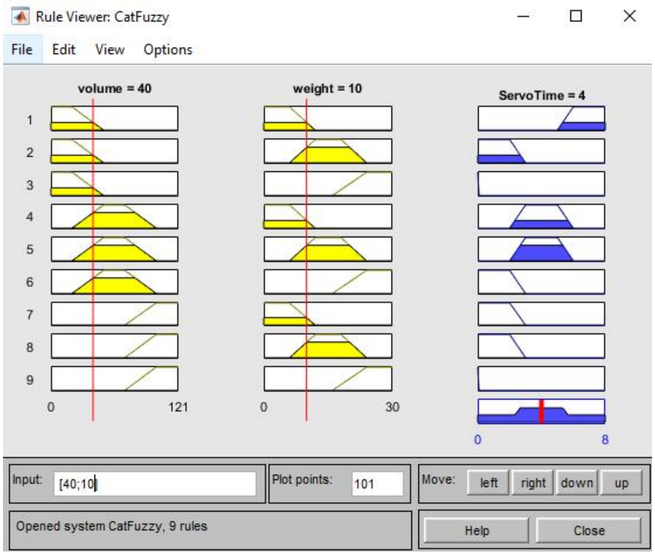

Fig. 4 Output of software testing.

Testing on the toolbox for the input volume value of 40 cm^3 and the input weight of 10 grams produces a ServoTime for 4 seconds. The output graph on a trapezoidal curve intersects the Fast curve, Awhile curve, and Long curve.

C. Mathematical Calculations

Mathematical calculations are carried out in several steps, namely:

1) Determine the Fuzzy Set

The fuzzy set is determined by finding the degree of membership in the membership function. With an input volume value of 40 cm^3 , it is found in "Empty" and "Middle". The input weight value of 10 grams is in "VeryLight" and "Light". The equations obtained based on equation (4), equation (5), equation (7), and equation (8) are:

Input Volume

$$\mu_{Ep}[40] = \frac{50-x}{30} = \frac{50-40}{30} = 0{,}33 \tag{13}$$

$$\mu_{Md}[40] = \frac{x-20}{30} = \frac{40-20}{30} = 0{,}66 \tag{14}$$

Input Weight

$$\mu_{VeL}[10] = \frac{12-x}{6} = \frac{12-10}{6} = 0{,}33 \tag{15}$$

$$\mu_{Lg}[10] = \frac{x-6}{6} = \frac{10-6}{6} = 0{,}66 \tag{16}$$

2) The Function Implication

The value of the degree of membership that has been obtained is entered into the rules to determine the implication function. The implication function is determined based on the MIN value because the fuzzy rules use the AND function. In this case, there are two rules based on Table III that fulfill the requirements, namely [R1], [R2], [R4], and [R5].

- [R1] : If Volume is Empty **and** Weight is VeryLight then ServoTime is Long.

$$\alpha_{R1} = \mu_{Ep} \cap \mu_{VeL} \tag{17}$$

$$\alpha_{R1} = min\ (\mu_{Ep} \cap \mu_{VeL})$$

$$\alpha_{R1} = min\ (0.33{,}0.33) = 0.33$$

- [R2] : If Volume is Empty **and** Weight is Light then ServoTime is Fast.

$$\alpha_{R2} = \mu_{Ep} \cap \mu_{Lg} \tag{18}$$

$$\alpha_{R2} = min\ (\mu_{Ep} \cap \mu_{Lg})$$

$$\alpha_{R2} = min\ (0.33{,}0.66) = 0.33$$

- [R4] : If Volume is Middle **and** Weight is VeryLight then ServoTime is Awhile.

$$\alpha_{R4} = \mu_{Md} \cap \mu_{VeL} \tag{19}$$

$$\alpha_{R4} = min\ (\mu_{Md} \cap \mu_{VeL})$$

$$\alpha_{R4} = min\ (0.66{,}0.33) = 0.33$$

- [R5] : If Volume is Middle **and** Weight is Light then ServoTime is Awhile.

$$\alpha_{R5} = \mu_{Md} \cap \mu_{Lg} \tag{20}$$

$$\alpha_{R5} = min\ (\mu_{Md} \cap \mu_{Lg})$$

$$\alpha_{R5} = min\ (0.66{,}0.66) = 0.66$$

3) Defuzzification

The value of the degree of membership that is already known will be converted into a decision form. The integral technique with the centroid method calculates the moment and area of the output curve used to obtain values using equation (21):

$$Z^* = \frac{\int \mu_x(z).zdz}{\int \mu_x(z)\ dz} \tag{21}$$

with,

Z = output composition result center.

Calculating the area is done by adding up the area of the five shaded areas on the output curve, namely:

- $A1 = 2.33 \times 0.33 = 0.7689$
- $A2 = \frac{0.33 \times 0.99}{2} = 0.16335$
- $A3 = 2.68 \times 0.66 = 1.7688$
- $A4 = \frac{0.33 \times 0.99}{2} = 0.16335$
- $A5 = 2.33 \times 0.33 = 0.7689$

Calculating moments using partial integrals, namely:

- $M1 = \int_{0}^{2.33} 0.33z\, dz = 0.8957685$
- $M2 = \int_{2.33}^{2.66} (z-2)z\, dz = 0.410553$
- $M3 = \int_{2.66}^{5.34} 0.66z\, dz = 7.0752$
- $M4 = \int_{5.34}^{5.67} (6-z)z\, dz = 0.896247$
- $M5 = \int_{5.67}^{8} 0.33z\, dz = 5.2554315$

Then the output value according to equation (21) is:

$$Z^* = \frac{14.5332}{3.6333} = 4$$

The result of defuzzification is that the center value on the output curve is 4 seconds for ServoTime.

4) Comparative Analysis

In this analysis, the test reference refers to the input volume of 40 cm^3 and the input weight of 10 grams. In each test, the input values used are set the same in order to compare the results obtained. The Arduino UNO test output shows the readings from the HC-SR04 sensor input and load cell sensor, which is 4 seconds for ServoTime. The output of the fuzzy control test on the toolbox is 4 seconds by entering the input volume and input weight values. And for the results of the output value obtained from manual mathematical calculations using the centroid method is 4 seconds. Mathematical calculations are carried out by taking all the numbers behind the comma in the calculation process to minimize the error value. From the three tests, the results obtained for the servo opening time is 4 seconds. Each test showed the same results. Means that the system used is accurate or does not have an error value, especially in the case study of the input value used.

IV. Conclusions

The FLC-based automatic cat feeding system has been successfully developed. This FLC-based automatic cat feeding research is based on the value obtained from the need for a cat's feeding portion in one day as a reference value for designing software. The FLC design uses the Mamdani method with 2 inputs and 1 output, and 9 rules. The test was carried out for the volume input value of 40 cm^3 with the input weight of 10 grams. System testing was carried out three times, namely hardware testing (Arduino UNO), software testing for fuzzy control, and testing using mathematical calculations. The output results in the form of servo opening time obtained with three tests give the same result of 4 seconds. These results indicate the system is quite feasible to use for feeding cats.

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