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Utilizing fuzzy logic to create a prototype robot for load detection

Muhammad Furqon Siregar[1], Chairul Imam[2]

[1]Department Of Informatics, Battuta University, Medan, Indonesia

[2]Department Of Information Technology, Battuta University, Medan, Indonesia

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ABSTRACT

The application of fuzzy logic in a load-lifting arm robot is covered in this work. Input values are computed using fuzzy logic to prevent inappropriate power usage caused by variations in load weight. The robot's ability to successfully lift the load is the performance that is being evaluated. To choose the motor rotation, the system should calculate the mass of the load. System design is done with an Arduino Uno. For pinching and driving levers, servo motors are used. A mass sensor is used to estimate the mass of the load. Robot construction limits the load to a maximum weight of 900 grams in order to assess robot performance. The findings demonstrate that using Tsukamoto's fuzzy logic model improves accuracy outcomes when determining the degree of slope servo.

Corresponding Author:

Muhammad Furqon Siregar,
Department Of Informatics,
Battuta University,
Jalan Sekip No.1, Medan Indonesia, 20111
Email: muhammad.furqon.srg@gmail.com

1. INTRODUCTION

Many human tasks are made easier by technology, such as soft computing. At this point, soft computing can be used, where all instruments will be fully automated. This methodology makes use of computer science computation algorithms that are designed to take advantage of tolerance for errors, uncertainty, and partial truth . For instance, consider the technologies we use on a daily basis today—the air conditioner, refrigerator, washing machine, and many more. The fuzzy logic technique has been implemented in several technological gadgets. Artificial intelligence, or the body of knowledge that enables computers and other electronic devices to perform tasks that people typically perform, includes the study of fuzzy logic (Todorovic & Simic, 2020).

In order to further improve the controller parameters, a genetic algorithm has been used to regulate the design of the fuzzy logic controller (Tavakoli & Karimpour, 2021). A substitute for contemporary control systems with a steady system response is the fuzzy logic controller. Three phases are involved in employing fuzzy logic to construct a control system: fuzification, rule assessment, and defuzification. Every one of these procedures has an impact on the controlled system response (Siregar & Chairul Imam, 2022). Robot controllers can be designed using fuzzy logic, which makes decisions about how to apply particle parameter swarm optimization (PSO) in a given situation based on behavior. Fuzzy logic is applicable to microcontroller robots (Furqon Siregar, Muhammad Imam & Nasution, 2020). The availability of open source physical computing platforms has made microcontroller use more and easier.

Wheeled robot balance can be controlled by combining fuzzy logic functions with soft computing approaches (Furqon, 2022). For a robotic prototype model, fuzzy logic can be constructed utilizing many microcontrollers and the behavior-based approach (Abdul & Hambali, 2020). Load lifting can also be controlled using fuzzy logic commands, which involve communication between the controller and the movement of the lever and cap (Zulkifli et al., 2020). To stabilize the movement of lift levers and clamps to lift things classified as Easy, medium, and heavy loads, researchers are concentrating on developing fuzzy logic method for load lifting robots. choosing input parameters, specifically from the prototype's mass sensor.

2. RESEARCH METHOD

a. Robot Prototype

Acrylic is used in the construction of the prototype robot as the foundation for its parts and framework. The prototype has a minimal ATmega328 system board, one mass sensor, four complete DC motors and tires, five servo motors, and a driver motor for wheel driving. For the robot to move as shown, these parts are interconnected and supported by four wheels in Figure 1.

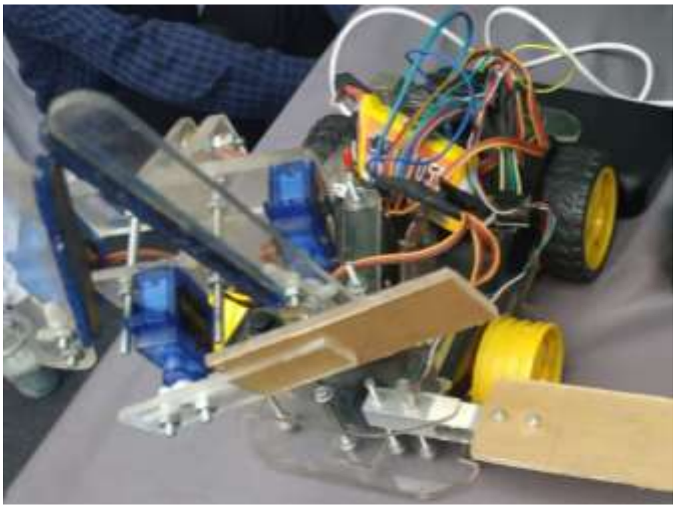

Figure 1. Robot prototype

b. Software Design

Acrylic serves as the foundation for the robot's components and its framework in this prototype version. The prototype includes four complete DC motors and tires, five servo motors, a driver motor for wheel driving, one mass sensor, and an ATmega328 minimal system board. As seen, these parts work together and are supported by four wheels to propel the robot. Software systems are created using C language programs that are edited via scratch editors, as Figure 2 illustrates. The goal of this program is to design the functional system for each component.

Figure 2. Desktop programming using Arduino IDE

A functional flowchart is created as shown in Figure 3 in order to implement the suggested system. Ensuring proper robot operation and easy implementation of fuzzy logic programs are the main objectives.

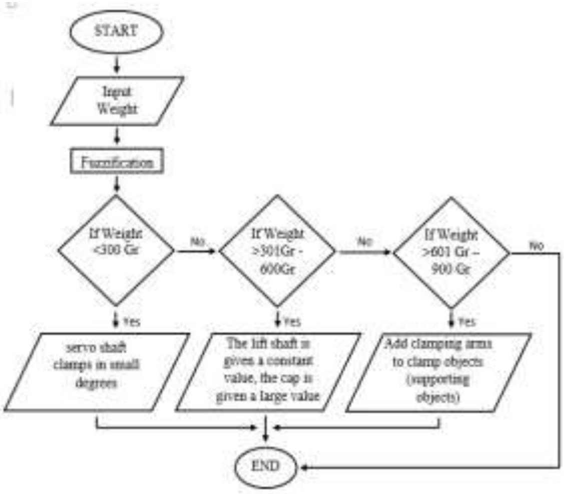

Figure 3. Flowchart of load lifting process

c. Interconnected System

The mass of an object is initially determined by the system using mass sensors. Data from mass sensors are interpreted by the microcontroller program using its fuzzy logic feature. After completing a load analysis, the burden is discharged. Four servo motors work together in this partnership.

d. Load Variable

Three language attributes are used in the design of fuzzy membership functions for load variables. These attributes have the following values: E(Easy) (0-300), M(Medium) (200-600), and H(Heavy) (500-900), as shown in Figure 4.

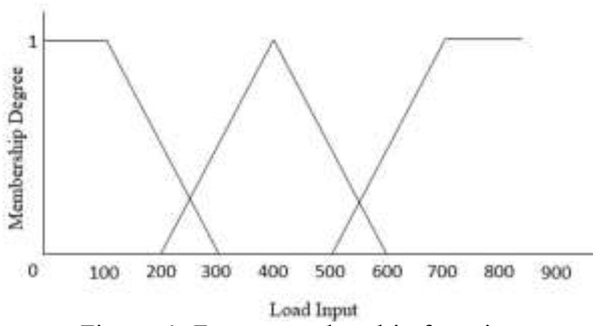

Figure 4. Fuzzy membership functions

The following set of formulas can be used to compute the load variable's membership function:

arranged according to variables Load $_{(Easy)}$: $\mu M_{[X]} = \begin{cases} 1, & x \leq 200 \\ \frac{300-x}{300-200}, & 200 \leq x \leq 300 \\ 0, & x \geq 300 \end{cases}$

Set for variables Load $_{(Normal)}$: $\mu M_{[X]} = \begin{cases} 1, & x = 400 \\ \frac{x-200}{400-200}, & 200 \leq x \leq 400 \\ \frac{600-x}{600-400}, & 400 \leq x \leq 600 \\ 0, & x \leq 200,\ x \geq 600 \end{cases}$

Set for variables Load $_{(Weight)}$: $\mu M_{[X]} = \begin{cases} 1, & x \geq 600 \\ \frac{x-500}{600-500}, & 500 \leq x \leq 600 \\ 0, & x \leq 500 \end{cases}$

e. Fuzzy Rules

Fuzzy rules which use in this research are defined for Tsukamoto's fuzzy inference system. There are 3 rules for each servo which on Table 1, Table 2, and Table 3.

Table 1. Fuzzy rules on servo 1 and 2

Rule		Load		Servo 1,2
1	IF	Easy	THEN	Low
2	IF	Normal	THEN	Middle
3	IF	Weight	THEN	High

The author has created rules in the table above that determine when two servo motors will move when a certain value is reached.

Table 2. List of fuzzy rules on servo 3

Rule		Load		Servo 3
1	IF	Easy	THEN	Low
2	IF	Normal	THEN	High
3	IF	Weight	THEN	High

Table 3. List of fuzzy rules on servo 4

Rule		Load		Servo 4
1	IF	Easy	THEN	Middle
2	IF	Normal	THEN	Middle

3	IF	Weight	THEN	High

Rules governing the movement of servos 3 and 4 are shown in the second and third tables, provided that the values are achieved in compliance with the guidelines.

The rule for the degres percentages are:
1. Low : 20%
2. Middle : 30%
3. High : 40%

3. RESULTS AND DISCUSSIONS

In order to evaluate the system, experiments were performed several times. After obtaining the evaluated parameters, results are reported by using tables and graphs. The average value of the four motor servos were than obtained.

a. Testing Load with mass 50 gram

Each test must first be inference, looking for the degree of membership value for each fuzzy set variable, as described:

Input Load Variable
μEasy(50) = 1
μNormal(50) = 0
μWeight(50) = 0

Next, we will proceed with the fuzzyfication process after obtaining membership degrees. The computation procedure, which is done next and follows preset guidelines, is the next phase.

Rule on Servo 1 And 2
[R1] IF Load = Easy THEN Servo = Low
α-predicate1 = min μEasy(50)
= min (1) = 1
[R2] IF Load = Normal THEN Servo
= Middle α-predicate2
= min μNormal(50)
= min (0) = 0
[R3] IF Load = Weight THEN Servo = High α-predicate3
= min μWeight(50)
= min (0) = 0

[Z1] Zmax – α-p1 (Zmax – Zmin)
= 40 – 1 . (40 – 20)
= 40 – 20 = 20
[Z2] Zmax – α-p2 (Zmax – Zmin)
= 40 – 0 . (40-30)
= 40 – 0 = 40
[Z3] Zmax – α-p3 (Zmax – Zmin)
= 40 – 0 . (40-40)
= 40 – 0 = 40

Defuzzyfication Process in Servo 1 And 2
The defuzzyfication process uses the Tsukamoto model inference in testing the servo 1 as follows:

Z Total = $\frac{(\alpha\text{-p1} * Z1) + (\alpha\text{-p2} * Z2) + (\alpha\text{-p3} * Z3)}{(\alpha\text{-p1} + \alpha\text{-p2} + \alpha\text{-p3})}$

= $\frac{(1 * 20) + (0 * 40) + (0 * 40)}{(1 + 0 + 0)}$

= $\frac{20}{1}$ = 20

From the calculation of testing the defuzzyfication process, it can be seen that the increase in servo degrees is 20% of the initial speed.

Rule on Servo 3

[R1] IF Load = Easy THEN Servo3 = Low
α-predicate1 = min µEasy(50)
= min (1) = 1

[R2] IF Load = Normal THEN Servo3 = High
α-predicate2 = min µNormal(50)
= min (0) = 0

[R3] IF Load = Weight THEN Servo3 = High
α-predicate3 = min µWeight(50)
= min (0) = 0

[Z1] Zmax - α-p1 (Zmax – Zmin)
= 40 – 1 . (40-20)
= 40 – 20 = 20

[Z2] Zmax - α-p2 (Zmax – Zmin)
= 40 – 0 . (40-40)
= 40 – 0 = 40

[Z3] Zmax - α-p3 (Zmax – Zmin)
= 40 – 0 . (40-40)
= 40 – 0 = 40

Defuzzyfication Process in Servo 3

The defuzzyfication process uses the Tsukamoto model inference in servo3 testing as follows:

Z Total = $\frac{(\alpha\text{-p1} * Z1) + (\alpha\text{-p2} * Z2) + (\alpha\text{-p3} * Z3)}{(\alpha\text{-p1} + \alpha\text{-p2} + \alpha\text{-p3})}$

= $\frac{(1 * 20) + (0 * 40) + (0 * 40)}{(1 + 0 + 0)}$

= 20

From the calculation of testing the defuzzyfication process, it can be seen that the increase in servo3 degrees is 20% of the initial speed.

Rule on Servo 4

[R1] IF Load = Easy THEN Servo 4 = Middle
α-predicate1 = min µEasy(50)
= min (1) = 1

[R2] IF Load = NormalTHEN Servo 4 = Middle
α-predicate2 = min µNormal(50)
= min (0) = 0

[R3] IF Load = Weight THEN Servo 4 = High
α-predicate3 = min µWeight(50)
= min (0) = 0

[Z1] Zmax - α-p1 (Zmax – Zmin)

$= 40 - 1 . (40\text{-}30)$
$= 40 - 10 = 30$

[Z2] Zmax - α-p2 (Zmax – Zmin)
$= 40 - 0 . (40\text{-}30)$
$= 40 - 0 = 40$

[Z3] Zmax - α-p3 (Zmax – Zmin)
$= 40 - 0 . (40\text{-}40)$
$= 40 - 0 = 40$

Defuzzyfication Process in Servo 4

The defuzzyfication process uses the Tsukamoto model inference in servo4 testing as follows:

$$Z\ Total = \frac{(\alpha\text{-}p1 * Z1) + (\alpha\text{-}p2 * Z2) + (\alpha\text{-}p3 * Z3)}{(\alpha\text{-}p1 + \alpha\text{-}p2 + \alpha\text{-}p3)}$$
$$= \frac{(1 * 30) + (0 * 40) + (0 * 40)}{(1 + 0 + 0)}$$
$$= 30$$

From the calculation of testing the defuzzyfication process, it can be seen that the increase in servo4 degrees is 30% of the initial speed.

The movement of the relay and potential becomes more stable in relation to the provided value, according to the calculations and experiments that have been conducted. The percentage of movement increases proportionately to the applied load and is constant with respect to the servo's potential degree. By adding up each percent of the test and dividing by the total number of inputs, the average value for each degree may be obtained from the relay and potentiometer. Thus, by using fuzzy logic on the robot prototype, this average result demonstrates stability.

4. CONCLUSION

Based on the results of the testing, it can be said that the tool design idea can apply fuzzy logic to create a prototype that employs uncertain number analysis. The results of the researcher's experiments above demonstrate this application, which allows any movement to be processed with a value that is randomly obtained. The findings of the study demonstrate the high degree of accuracy with which the Tsukamoto fuzzy logic model, which calculates the servo's tilt, can determine the tilt between its four constituent parts. Servo 1 and 2 are the object hooks; servo 3 is the supporting object, situated below; and servo 4 is the object lifting servo. The additional results from the research and earlier study suggest that fuzzy logic is a better use for this design than using direct servo movements just for prototyping. The consistency of movement between servo-arm communications demonstrates this. More exact control over the steadiness of the movement is possible with fuzzy logic. However, in this prototype, the servo's inclination will not change, and if fuzzy logic is not applied, the work simulation throughout the lifting process will be less accurate and unstable. In order to produce a design that will improve the way study results evolve in the future and the chances for their application in further research, the author also provides suggestions for integrating two different approaches or algorithms.

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