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Comparison Analysis of Fuzzy Sugeno & Fuzzy Mamdani for Household Lights

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***Abstract*— The rapid growth of knowledge and technology in the IoT field encourages scientists to make discoveries in facilitating daily activities by utilizing artificial intelligence, one of which is the Smart Home. Smart home technology is needed that has better advantages over existing building materials, one of which is home lighting or the use of lights. If all this time, houses still use manual control to turn the lights on and off, it will potentially cause the lights to turn on still even though they are not needed, for that we need a method used in the implementation of automatic light control. From several studies, the Fuzzy method is widely used in this case. This method has several models, but the author uses the Fuzzy Mamdani method and the Sugeno method to apply in this study. The variable at the input is the LDR sensor, while the output is a lamp. From the trial results of the two methods, and accuracy test was sought as a parameter for the better ana method. It can be concluded that the Sugeno method has a better accuracy rate of 88.25%, compared to Mamdani's, which is only 84.5%.**

***Keywords*— Smart House, Light Control, Fuzzy Sugeno, Fuzzy Mamdani**

I. INTRODUCTION

Fuzzy logic is one form of soft computing. Prof. Lotfi A. Zadeh first introduced fuzzy logic in 1965. The basis of fuzzy logic is fuzzy set theory. In fuzzy set theory, the role of membership degree as a determinant of the existence of elements in a set is crucial. The value of membership or the degree of membership or membership function is the main characteristic of reasoning with fuzzy logic [1]. There are several definitions of fuzzy logic, including:
1. Fuzzy logic is logic used to explain ambiguity set logic that resolves the ambiguity.
2. Fuzzy logic provides a way to convert a linguistic statement into a numeric one.

Fuzzy logic has membership degrees in the range of 0 to 1. In contrast to digital logic, which only has two values of 1 or 0. Fuzzy logic is used to translate a quantity expressed using language (linguistics), for example, the amount of vehicle speed expressed slowly, somewhat fast, fast, and very fast. Moreover, fuzzy logic shows the extent to which a value is actual and the extent to which a value is false [2].

Fuzzy logic is appropriate to map an input space into an output space. Fuzzy is expressed in degrees of membership and degrees of truth. Therefore something can be said to be partly right and partly wrong simultaneously [3].

Smart Home is a combined application of technology and services devoted to the home environment with specific functions to improve its residents' safety, efficiency, and comfort. Intelligent home systems usually consist of monitoring devices control devices, and automatically, several devices can be accessed using a computer [4].

The Smart Home itself is an idea for home users to manage parts of their homes that are integrated into smartphones or other gadgets. To improve the quality of life of its users and manage the house properly. A crucial aspect is the security aspect needed by its users [5]. In general, there are three methods of fuzzy inference systems used in fuzzy logic: Tsukamoto, Mamdani, and Sugeno methods [6].

A. Tsukamoto Method

The Tsukamoto method is an extension of monotonous reasoning. Every consequence of the rule in the form of IF-THEN must be presented with a fuzzy set with a monotonous membership function. As a result, the inference output of each rule is given in a crisp (crisp) based on the -predicate. The final result is obtained using the weighted average.

B. Mamdani Method

For this method, for each rule in the form of implication ("cause and effect"), the antecedent in the form of conjunction (AND) has a membership value in the form of a minimum (MIN), while the combined consequent is in the form of a maximum (MAX) because the set of rules is independent (not interdependent).

C. Sugeno method

Reasoning with the Sugeno method is almost the same as Mamdani's reasoning; only the system output (consequent) is not a fuzzy set but a constant or linear equation. Takagi

Sugeno Kang introduced this method in 1985, which is often called the TSK method..

II. RESEARCH METHOD

A. *Previous Research*

Smart Home is a combined application of technology and services devoted to the home environment with specific functions that aim to improve its residents' safety, efficiency, and comfort. Intelligent home systems usually consist of monitoring devices control devices, and automatically several devices can be accessed using a computer [7]

The Smart Home itself is an idea for home users to manage parts of their homes that are integrated into smartphones or other gadgets. To improve the quality of life of its users and manage the house properly. A crucial aspect is the security aspect needed by its users [8].

The electricity crisis is a significant problem for the Indonesian nation, which has the fourth-largest population after China, India and America. The government conveys electricity savings to the community to limit the use of electrical energy, especially in their home environment. People's behaviour becomes different when using electricity outside the home, such as in the office/agencies. Someone at work often does waste. At the same time, half of a person's life is spent at work [9].

Lighting is an essential factor in carrying out activities. However, the lighting that Excess can also cause discomfort in activities. This research aims to examine the intensity of natural lighting in the COT meeting room of the Faculty of Engineering at Hasanuddin University [10]. The type of research used by the researcher is quantitative research and using the direct data collection method using a lux meter measuring instrument then presented in tabular form. This study concludes that the intensity of natural light in the COT building's 1st floor, 2nd floor, and 3rd-floor meeting rooms all exceed the 300 lux standard. The average light intensity outside the building with clear sky conditions in the morning of 29950 lux, 18360 lux during the day and 14550 lux in the afternoon [11].

Average intensity light on the outside of the building with cloudy sky conditions in the morning of 9200 lux, afternoon day is 8750 lux, and afternoon is 9350 lux [12]. The average intensity of light outside buildings with cloudy sky conditions in the morning of 3250 lux, in the afternoon of 6610 lux and in the afternoon of 5425 lux. The amount of natural light intensity outside the building with Any sky conditions significantly affects the natural lighting entering the building. The greater the light intensity outside the building, the greater the incoming light to the building [13].

B. *Flow Chart of Research*

In this part of the stage, the researcher will explain the flow of the research carried out [14]. The stages of this stage consist of literature study and problem identification, data collection, drawing conclusions, and providing recommendations for the results of the data analysis carried out. A complete research flow can be seen in Figure 1 as follows:

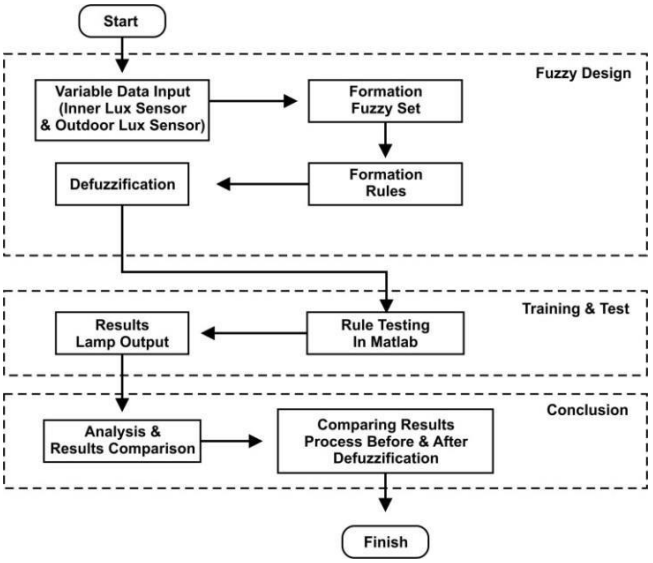

Fig. 1 Flow Chart of Research

C. *Fuzzy Logic Control Design*

The tool's design in this study uses fuzzy logic control to adjust the intensity of the light according to the brightness of the room. The input used as a variable result from indoor and outdoor lux sensor readings. Meanwhile, the fuzzy inference process used is the Fuzzy Sugeno and Mamdani methods [15].

D. *Fuzzy Process Flow*

Fuzzy will produce decisions or conclusions with several stages, including the formation of fuzzy sets, application of implications functions, the composition of rules, and the last one is defuzzification [16]. The fuzzy process flow is shown in Figure 2.

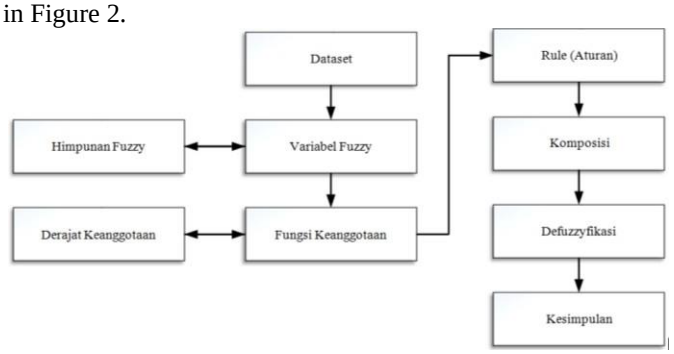

Fig. 2 Fuzzy Process Flow

III. RESULTS AND DISCUSSION

A. *Dataset*

The dataset or material in this study is a test of the external sensor and the internal sensor to produce a lamp lumen output or output [17]. This testing phase is carried out to determine which method is better between Fuzzy Sugeno and Fuzzy

Mamdani as a decision-making process or conclusion because the results obtained are most in line with human instincts. The trial was carried out using sample data obtained from test data carried out seven times, as shown in Table I..

B. Fuzzy Set

In the Fuzzy Logic Control design, input and output are also determined, where at the input, there are two variables, namely the Inner Lux sensor and Outdoor Lux sensor, while the output uses a lamp variable [18].

There are five conditions in the fuzzy set on the Inner Lux Sensor variable, namely: Dark, Little Dark, Dim, Little Bright, and Bright, and meanwhile on the Outdoor Lux Sensor, and there are three fuzzy set conditions, namely: Dark, Cloudy, and Sunny. In comparison, the fuzzy sets on the output lights are Off Little Dark, Dim, Little Bright, and Bright. The universe talks about three functions (Input 1, Input 2, and Output) in the range 0-128 [19].

TABLE I
FUZZY SET

Function	Variable	Fuzzy Set	Range	Domain
Input 1	Inner Lux Sensor	Dark	0-128	0 - 32
		Little Dark		0 - 64
		Dim		32 - 96
		Little Bright		64 - 128
		Bright		96 - 128
Input 2	Outdoor Lux Sensor	Dark	0-128	0 – 64
		Cloudy		0 - 128
		Sunny		64 - 128
Output	Lamp	Off	0-128	128
		Little Dark		96
		Dim		64
		Little Bright		32
		Bright		0

C. Fuzzy Logic Rule

TABLE 2
RULES

		Inner Lux Sensor				
		Dark	**Little Dark**	**Dim**	**Little Bright**	**Bright**
Outdoor Lux Sensor	**Dark**	Bright	Little Bright	Little Bright	Little Bright	Dim
	Cloudy	Little Bright	Dim	Dim	Dim	Little Dark
	Sunny	Dim	Little Dark	Little Dark	Little Dark	Off

From the definition of the rules as shown in the table above, there are 15 fuzzy rules:

[R1] IF (Inner Lux Sensor is Dark) AND (Outdoor Lux Sensor is Dark) THEN (Lamp is Bright)

[R2] IF (Inner Lux Sensor is Dark) AND (Outdoor Lux Sensor is Cloudy) THEN (Lamp is Little Bright)

[R3] IF (Inner Lux Sensor is Dark) AND (Outdoor Lux Sensor is Sunny) THEN (Lamp is Dim)

[R4] IF (Inner Lux Sensor is Little Dark) AND (Outdoor Lux Sensor is Dark) THEN (Lamp is Little Bright)

[R5] IF (Inner Lux Sensor is Little Dark) AND (Outdoor Lux Sensor is Cloudy) THEN (Lamp is Dim)

[R6] IF (Inner Lux Sensor is Little Dark) AND (Outdoor Lux Sensor is Sunny) THEN (Lamp is Little Dark)

[R7] IF (Inner Lux Sensor is Dim) AND (Outdoor Lux Sensor is Dark) THEN (Lamp is Little Bright)

[R8] IF (Inner Lux Sensor is Dim) AND (Outdoor Lux Sensor is Cloudy) THEN (Lamp is Dim)

[R9] IF (Inner lux sensor is Dim) AND (Outdoor Lux Sensor is Sunny) THEN (Lamp is Little Dark)

[R10] IF (Inner Lux Sensor is Bright) AND (Outdoor Lux Sensor is Dark) THEN (Lamp is Little Bright)

[R11] IF (Inner Lux Sensor is Slightly Bright) AND (Outdoor Lux Sensor is Cloudy) THEN (Lamp is Dim)

[R12] IF (Inner Lux Sensor is Little Bright) AND (Outdoor Lux Sensor is Sunny) THEN (Lamp is Little Dark)

[R13] IF (Inner Lux Sensor is Bright) AND (Outdoor Lux Sensor is Dark) THEN (Lamp is Dim)

[R14] IF (Inner Lux Sensor is Bright) AND (Outdoor Lux Sensor is Cloudy) THEN (Lamp is Little Dark)

[R15] IF (Inner Lux Sensor is Bright) AND (Outdoor Lux Sensor is Sunny) THEN (Lamp is Off)

D. Test Result

This test was conducted to test the light output between the Fuzzy Sugeno and Mamdani methods, with the same input value. The test was carried out using MATLAB software with the Fuzzy toolbox. The test was carried out seven times, presented in the data in table 3.

TABLE 3
TEST RESULT

Trial	Lux Sensor (Input)		Lamp (Output)	
	Inner	**Outside**	**Fuzzy Sugeno**	**Fuzzy Sugeno**
1	20	40	40	51,2
2	40	75	69,5	70
3	50	60	62	61,9

4	64	64	64	64
5	75	50	57	56,8
6	90	90	77	77,3
7	120	60	86	86

From the table above, the results were obtained from Fuzzy Sugeno and Fuzzy Mamdani, where output is the reference value. Then look for the level of accuracy as a parameter which method is better.

TABLE 4
SUGENOFUZZYACCURACYTEST

Sugeno Fuzzy Accuracy Test				
No	Output	Fuzzy Sugeno	Error (Output-Fuzzy Sugeno)	Error % (Error/Output x 100%)
1	40	40	0	0
2	75	69,5	5,5	7,3
3	60	62	-2	3,3
4	64	64	0	0
5	50	57	-7	14
6	90	77	13	14,4
7	60	86	-26	43,3
Total Error %				82,3
Average Error %				11,75

Accuracy = 100% - 11,75% = 88,25 %

So, the accuracy obtained is 88,25 %.

TABLE 5
MAMDANI FUZZYACCURACYTEST

Mamdani Fuzzy Accuracy Test				
No	Output	Fuzzy Mamdani	Error (Output-Fuzzy Sugeno)	Error % (Error/Output x 100%)
1	40	51,2	-11,2	28
2	75	70	5	6,7
3	60	61,9	-1,9	3,1
4	64	64	0	0
5	50	56,8	-6,8	13,6
6	90	77,3	12,7	14,1
7	60	86	-26	43
Total Error %				108,5
Average Error %				15,5

Accuracy = 100% - 15,5% = 84,5 %

So, the accuracy obtained is 84,5 %.

From the results of the accuracy-test between the Fuzzy Sugeno and Fuzzy Mamdani methods in tables 4 and 5, it can be concluded that Sugeno's method has a better accuracy rate of 88,25%, compared to Mamdani's, which is only 84,5%. Moreover, in the formulation of the problem, it can be answered that the better method for this case is Fuzzy Sugeno's method.

IV. CONCLUSIONS

Based on the test results of the external lux sensor data and the internal lux sensor, using the Sugeno fuzzy and Mamdani fuzzy methods, several conclusions were obtained, including:

1. The study results conclude that the input value of the lux sensor affects the value of the lamp output.
2. In testing the system using the Sugeno model, an accuracy value of 88,25% was obtained, while the Mamdani model obtained an accuracy value of 84,5%, so it can be concluded that Sugeno's model is better and more accurate than Mamdani's model.

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