Application of The Fuzzy Grid Partition-Based Mamdani Method for Eligibility of Employee Salary Increases at the North Sumatera Blind Foundation

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ABSTRACT- Fuzzy grid partition has been used to produce appropriate and optimal output. The output of several fuzzy inference methods such as the Tsukamoto method and the Mamdani method have been improved by applying grid partitions. This study aims to apply the fuzzy grid partition-based mamdani method to determine the feasibility of increasing employee salaries at the North Sumatra Blind Education Foundation. The stages of the method are carried out starting with determining the number of partitions, forming fuzzy sets, carrying out the process of implicit rules, carrying out rule composition by selecting the maximum value of feasible and infeasible decisions, and finally carrying out the defuzzification process to obtain the calculation of the crips value. Attributes or features for selecting the eligibility for a salary increase are employee status, class status, years of service and benefits received. The results of the research get a decision for each employee whether it is appropriate to receive a salary increase or not. From one sample data tested on sample X7, the result of defuzzification (Z) is 5. Based on the table of feasible and inappropriate decisions, the value of Z = 5 is in a feasible decision.

Keywords : Mamdani Method, Fuzzy Grid Partition, Eligibility, Salary Increase

1. INTRODUCTION

In the process of determining employee salary increases in a company, there are many obstacles or problems that must be faced, including time efficiency, the number of variable comparisons tested, decision making whether the employee is entitled to a salary increase or not and the number of data files processed, namely employee data [1].

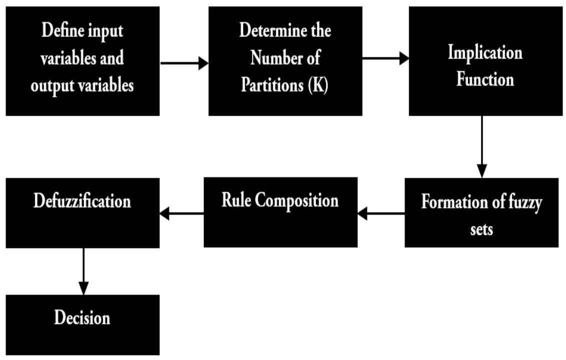
To assist decision makers in dealing with various structured and unstructured problems using data and models, a decision support system is needed [2]. Decision support systems have capabilities that are almost the same as an expert where the level of decision accuracy is high and performance is fast [3], [4].

One of the techniques that can be applied to a decision support system for determining the eligibility of a salary increase is the Mamdani method of fuzzy inference system [5], [6]. The Mamdani method has been widely used for various control devices which is the beginning of fuzzy technology and has the advantage of being able to express concepts that are difficult to formulate and use fuzzy membership functions in making objective observations of subjective values, making it easier to make decisions that are full of uncertainties. The application of the Mamdani method has also been widely used for various optimization problems [7]. The Mamdani method based on fuzzy grid partition produces optimal output in decision making [8].

This research is the application of fuzzy grid partition to the inference system of the Mamdani fuzzy method to provoke the feasibility of increasing employee salaries. This study aims to produce optimal output in decision making to determine the feasibility of a salary increase for employees of the North Sumatera Blind Education Foundation.

2. METHODOLOGY

To complete this research, it is necessary to have a framework with clear stages. The stages of the research framework for applying fuzzy grid partition-based mamdani method for eligibility of employee salary increases at the North Sumatra Blind Foundation can be seen in Figure 1 below [8].



Source: results of research processing
Figure 1. Research Framework

2.1 Define Input Variables and Output Variables.

The variables for determining the feasibility of a salary increase consist of input variables and output variables. Input variables consist of employee status, class status, years of service, receiving benefits.

While the output variable is a decision. The domain of each variable can be seen in table 1 below.

Table 1. Input variables and output variables

Variable		Linguistic Variables	Domain
Input	Employee Status	Constantly	0 – 6
		Changed Up	4 – 10
	Class Status	Up	7 – 10
		Constantly	3 – 8
		New	0 – 4
	Work Period	Long	10 – 40
		New	0 – 15
	Allowance Recipient	Many	3 – 5
		Moderate	2 – 4
		Few	0 – 3
Output	Decision	Feasible	3 – 10
		Not Feasible	0 – 4

Source: results place

2.2 Determine the Grid Partition (K) and the formation of fuzzy sets

The number of grid partitions (K) = 2, the membership function which is calculated as follows:

$$\mu(x) = \frac{b-x}{b-a} \quad \text{.............................(1)}$$

where:

$\mu(x)$ = membership function x

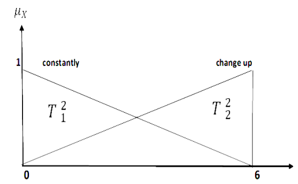
$x = object\ value\ for\ each\ attribute$

$b = upper\ limit$

$a = lower\ limit$

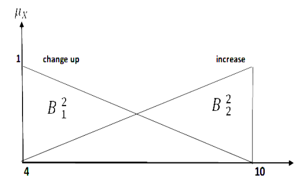
The membership function for each variable is as follows:

a. Employee Status (ES) Variable



$$\mu_{EST_1^2} = \frac{6-x}{6}$$

$$\mu_{EST_2^2} = \frac{x-0}{6}$$

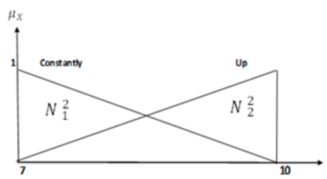


$$\mu_{ESB_1^2} = \frac{10-x}{6}$$

$$\mu_{ESB_2^2} = \frac{x-4}{6}$$

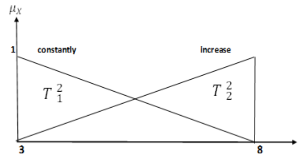
Source: results of research processing

b. Class Status (CS) Variable



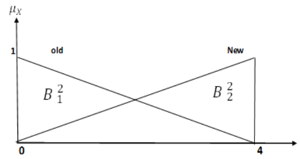
$$\mu_{CS\,N_1^2} = \frac{10-x}{3}$$

$$\mu_{CS\,N_2^2} = \frac{x-7}{3}$$



$$\mu_{CS\,T_1^2} = \frac{8-x}{5}$$

$$\mu_{CS\,T_2^2} = \frac{x-3}{5}$$

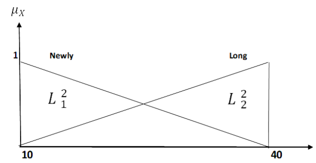


$$\mu_{CS\,B_1^2} = \frac{4-x}{4}$$

$$\mu_{CS\,B_2^2} = \frac{x-0}{4}$$

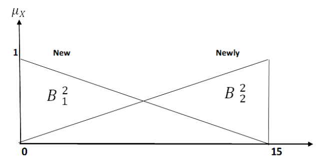
Source: results of research processing

c. Work Period Variable (WP)



$$\mu_{WP\,L_1^2} = \frac{40-x}{30}$$

$$\mu_{WP\,L_2^2} = \frac{x-10}{30}$$

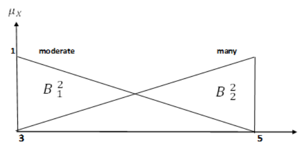


$$\mu_{WP\,B_1^2} = \frac{15-x}{15}$$

$$\mu_{WP\,B_2^2} = \frac{x-0}{15}$$

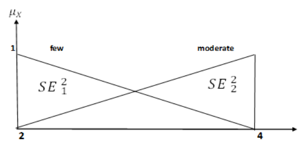
Source: results of research processing

d. Allowance Recipient Variable (AR)



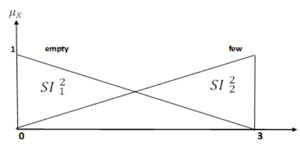
$$\mu_{AR\,B_1^2} = \frac{5-x}{2}$$

$$\mu_{AR\,B_2^2} = \frac{x-3}{2}$$



$$\mu_{AR\,SE_1^2} = \frac{4-x}{2}$$

$$\mu_{ARSE_2^2} = \frac{x-2}{2}$$



$$\mu_{AR\,SI_1^2} = \frac{3-x}{3}$$

$$\mu_{AR\,SI_2^2} = \frac{x-0}{3}$$

Source: results of research processing

2.3 Implication of Function

The rule for two dimensional grid partition is define as [9]:

$$R_{ij}^{K} :\ IF\ x_i\ is\ A_i^K\ AND\ x_j\ is\ A_j^K\ THEN\ C \quad \text{........(2)}$$

Where :

R_{ij}^{K} is the if-then fuzzy label rule

A_i^K and A_j^K is a fuzzy subset of intervals [1,0]
K is partition
C is conclusion
i and j is 1,2, …, K

There are 18 function rules that are implied in the Mamdani method with the application of the Fuzzy Grid Partition, namely:

[R1] IF ES T_1^2 AND CS N_1^2 AND WP L_1^2 AND AR B_1^2 THEN Feasible Decision.
[R2] IF ES T_2^2 AND CS N_2^2 AND WP L_2^2 AND AR B_2^2 THEN Feasible Decision.
[R3] IF ES T_1^2 AND CS N_1^2 AND WP L_1^2 AND AR SE_1^2 THEN Feasible Decision.
[R4] IF ES T_2^2 AND CS N_2^2 AND WP L_2^2 AND AR SE_2^2 THEN Feasible Decision.
[R5] IF ES T_1^2 AND CS N_1^2 AND WP L_1^2 AND AR SI_1^2 THEN Feasible Decision.
[R6] IF ES T_2^2 AND CS N_2^2 AND WP L_2^2 AND AR SI_2^2 THEN Feasible Decision.
[R7] IF ES B_1^2 AND CS N_1^2 AND WP L_1^2 AND AR SE_1^2 THEN Feasible Decision.
[R8] IF ES B_2^2 AND CS N_2^2 AND WP L_2^2 AND AR SE_2^2 THEN Feasible Decision.
[R9] IF ES B_1^2 AND CS N_1^2 AND WP L_1^2 AND AR SI_1^2 THEN Feasible Decision.
[R10] IF ES B_2^2 AND CS N_2^2 AND WP L_2^2 AND AR SI_2^2 THEN Feasible Decision.
[R11] IF ES T_1^2 AND CS T_1^2 AND WP B_1^2 AND AR SI_1^2 THEN Not Feasible Decision.
[R12] IF ES T_2^2 AND CS T_2^2 AND WP B_2^2 AND AR SI_2^2 THEN Not Feasible Decision.
[R13] IF ES T_1^2 AND CS B_1^2 AND WP B_1^2 AND AR SI_1^2 THEN Not Feasible Decision.
[R14] IF ES T_2^2 AND CS B_2^2 AND WP B_2^2 AND AR SI_2^2 THEN Not Feasible Decision.
[R15] IF ES T_1^2 AND CS B_1^2 AND WP B_1^2 AND AR SI_1^2 THEN Not Feasible Decision.
[R16] IF ES T_2^2 AND CS B_2^2 AND WP B_2^2 AND AR SI_2^2 THEN Not Feasible Decision.
[R17] IF ES B_1^2 AND CS B_1^2 AND WP B_1^2 AND AR SI_1^2 THEN Not Feasible Decision.
[R18] IF ES B_2^2 AND CS B_2^2 AND WP B_2^2 AND AR SI_2^2 THEN Not Feasible Decision.

2.4 Rule Composition

From each rule, the results of the application of the implication function are used by the MAX method to perform composition between all rules. Determine the predicate maximum alpha value of the implication function with a feasible decision and the predicate maximum alpha value of an infeasible decision with the following formula:

$$\mu_K = \max\ (\mu_K\ Feasible\ \cap\ \mu_K\ Not\ Feasible) \quad ..(3)$$

2.5 Defuzzification

The defuzzification process uses the centriod method, where to determine the crisp Z value, the image shows one part. The section is calculated the area and moment of the membership value [10].

$$Z_0 = \frac{\int_a^b Z.\mu(z)dz}{\int_a^b \mu(z)dz} \quad \ldots\ldots(4)$$

where: Z = i-th domain value
μ(z) = the degree of membership of the point
Z_0 = defuzzification result value

3. RESULTS AND DISCUSSION

3.1 Research Result

The results of forming a fuzzy set obtain a degree of ownership for each input variable which can be seen in Table 2, Table 3, Table 4, and Table 5 below:

Table 2. Degree of Employee Status Membership

Employee	$\mu_{EST_1^2}$	$\mu_{EST_2^2}$	$\mu_{ESB_1^2}$	$\mu_{ESB_2^2}$
X1	0	0	0.17	0.83
X2	0	1	0.67	0.33
X3	0.33	0.67	1	0
X4	0	1	0.67	0.33
X5	0	1	0.67	0.33
X6	0.17	0.83	0.83	0.17
X7	0.17	0.83	0.83	0.17
X8	0.17	0.83	0.83	0.17
X9	0.17	0.83	0.83	0.17
X10	0	1	0.67	0.33
X11	0.17	0.83	0.83	0.17
X12	0.17	0.83	0.83	0.17
X13	0.17	0.83	0.83	0.17
X14	0.17	0.83	0.83	0.17
X15	0.17	0.83	0.83	0.17
X16	0	1	0.67	0.33
X17	0	1	0.67	0.33
X18	0	1	0.67	0.33
X19	0	1	0.67	0.33
X20	0	1	0.67	0.33
X21	0.17	0.83	0.83	0.17
X22	0.17	0.83	0.83	0.17
X23	0	0	0.83	0.67
X24	0	0	0.5	0.5
X25	0	0	0.5	0.5
X26	0.33	0.67	1	0
X27	0.33	0.67	1	0
X28	0.33	0.67	1	0
X29	0.33	0.67	1	0

Employee	$\mu_{EST_1^2}$	$\mu_{EST_2^2}$	$\mu_{ESB_1^2}$	$\mu_{ESB_2^2}$
X30	0.67	0.33	0	0
X31	0.33	0.67	1	0
X32	0.67	0.33	0	0
X33	0.67	0.33	0	0
X34	0.67	0.33	0	0

Source: data processing results

Table 3. Degree of Class Status Membership

Employee	$\mu_{CSN_1^2}$	$\mu_{CSN_2^2}$	$\mu_{CST_1^2}$	$\mu_{CST_2^2}$	$\mu_{CSB_1^2}$	$\mu_{CSB_2^2}$
X1	0	0	1	0	0.25	0.75
X2	1	0	0.2	0.8	0	0
X3	0.67	0.33	0	1	0	0
X4	1	0	0.2	0.8	0	0
X5	0.33	0.67	0	0	0	0
X6	0.33	0.67	0	0	0	0
X7	0.67	0.33	0	1	0	0
X8	1	0	0.2	0.8	0	0
X9	1	0	0.2	0.8	0	0
X10	1	0	0.2	0.8	0	0
X11	1	0	0.2	0.8	0	0
X12	0	0	0.4	0.6	0	0
X13	0.67	0.33	0	1	0	0
X14	0.67	0.33	0	1	0	0
X15	0.67	0.33	0	1	0	0
X16	1	0	0.2	0.8	0	0
X17	0.33	0.67	0	0	0	0
X18	1	0	0.2	0.8	0	0
X19	0	1	0	0	0	0
X20	0	1	0	0	0	0
X21	1	0	0.2	0.8	0	0
X22	0.67	0.33	0	1	0	0
X23	2	0	0.8	0.2	0	1
X24	2	0	0.8	0.2	0	1
X25	2	0	0.8	0.2	0	1
X26	2	0	0.8	0.2	0	1
X27	1	0	0.2	0.8	0	0
X28	0.67	0.33	0	1	0	0
X29	0	0	1	0	0.25	0.75
X30	0	0	1	0	0.25	0.75
X31	0	0	1	0	0.25	0.75
X32	0	0	1	0	0.25	0.75
X33	0	0	1	0	0.25	0.75
X34	0	0	1	0	0.25	0.75

Source: data processing results

Table 4. Degree of Work Period Membership

Employee	$\mu_{WPL_1^2}$	$\mu_{WPL_2^2}$	$\mu_{WPB_1^2}$	$\mu_{WPB_2^2}$
X1	0	0	0.93	0.06
X2	0.06	0.93	0	0
X3	0	0	0.8	0.2
X4	0.2	0.8	0	0
X5	0.17	0.83	0	0
X6	0.5	0.5	0	0
X7	0.43	0.57	0	0
X8	0.57	0.43	0	0
X9	0.63	0.37	0	0
X10	0.33	0.67	0	0
X11	0.63	0.37	0	0
X12	0.6	0.4	0	0
X13	0.8	0.2	0	0
X14	0.8	0.2	0	0
X15	0.93	0.06	0.2	0.8
X16	0.47	0.53	0	0
X17	0.37	0.63	0	0
X18	0.43	0.57	0	0
X19	0.57	0.43	0	0
X20	0.33	0.67	0	0
X21	0.93	0.06	0.2	0.8
X22	0.9	0.1	0.13	0.87
X23	0.93	0.06	0.2	0.8
X24	0	0	0.67	0.33
X25	0	0	0.6	0.4
X26	0	0	0.6	0.4
X27	0	0	0.6	0.4
X28	0	0	0.67	0.33
X29	0	0	1	0
X30	0	0	0.93	0.06
X31	0	0	0.93	0.06
X32	0	0	0.93	0.06
X33	0	0	0.93	0.06
X34	0	0	0.93	0.06

Source: data processing results

Table 5. Degree of Allowance Recipient Membership

Employee	$\mu_{ARB_1^2}$	$\mu_{ARB_2^2}$	$\mu_{ARSE_1^2}$	$\mu_{ARSE_2^2}$	$\mu_{ARSI_1^2}$	$\mu_{ARSI_2^2}$
X1	0	0	0	0	1	0
X2	1	0	0.5	0.5	0	1
X3	0	1	0	0	0	0
X4	0	0	0	0	1	0
X5	0.5	0.5	0	0	0	0

Employee	$\mu_{AR\,B_1^2}$	$\mu_{AR\,B_2^2}$	$\mu_{AR\,SE_1^2}$	$\mu_{AR\,SE_2^2}$	$\mu_{AR\,SI_1^2}$	$\mu_{AR\,SI_2^2}$
X6	0.5	0.5	0	0	0	0
X7	1	0	0.5	0.5	0	1
X8	0.5	0.5	0	0	0	0
X9	0	0	1	1	0.33	0.67
X10	1	0	0.5	0.5	0	1
X11	0.5	0.5	0	0	0	0
X12	1	0	0.5	0.5	0	1
X13	0	0	1	1	0.33	0.67
X14	0.5	0.5	0	0	0	0
X15	0.5	0.5	0	0	0	0
X16	1	0	0.5	0.5	0	1
X17	0	0	0	0	0.67	0.33
X18	1	0	0.5	0.5	0	1
X19	0	0	1	1	0.33	0.67
X20	0	0	0	0	0.67	0.33
X21	0	0	1	1	0.33	0.67
X22	0	0	1	1	0.33	0.67
X23	0.5	0.5	0	0	0	0
X24	0.5	0.5	0	0	0	0
X25	0.5	0.5	0	0	0	0
X26	1	0	0.5	0.5	0	1
X27	0	0	0	0	0.67	0.33
X28	0.5	0.5	0	0	0	0
X29	0	1	0	0	0	0
X30	0	0	0	0	1	0
X31	0.5	0.5	0	0	0	0
X32	0	0	0	0	1	0
X33	0	0	0	0	1	0
X34	0	0	0	0	1	0

Source: data processing results

As a calculation for one sample is used to process the function that is realized, namely employee X7, namely:

$\alpha_1 = \min[0.17; 0.67; 0.43; 1] = 0.17$
$\alpha_2 = \min[0.83; 0.33; 0.57; 0] = 0$
$\alpha_3 = \min[017; 067; 0.43; 0.5] = 0.17$
$\alpha_4 = \min[0.83; 0.33; 0.57; 0.5] = 0.33$
$\alpha_5 = \min[0.17; 0.67; 0.43; 0] = 0$
$\alpha_6 = \min[0.83; 0.33; 0.43; 1] = 0.33$
$\alpha_7 = \min[0.83; 0.67; 0.57; 0.5] = 0.5$
$\alpha_8 = \min[0.17; 0.33; 0.43; 0.5] = 0.17$
$\alpha_9 = \min[0.83; 0.67; 0.57; 0] = 0$
$\alpha_{10} = \min[0.17; 0.33; 0.43; 1] = 0.33$
$\alpha_{11} = \min[0.17; 0; 0; 0] = 0$
$\alpha_{12} = \min[0; 0.83; 0; 1] = 0$
$\alpha_{13} = \min[0.17; 0; 0; 0] = 0$
$\alpha_{14} = \min[0.83; 0; 0; 1] = 0$
$\alpha_{15} = \min[0.17; 0; 0; 0] = 0$
$\alpha_{16} = \min[0.83; 0; 0; 1] = 0$
$\alpha_{17} = \min[0.83; 0; 0; 0] = 0$
$\alpha_{18} = \min[0.17; 0; 0; 1] = 0$

The maximum value of the predicate alpha of the implication function with a feasible decision is $\alpha = 0.33$ and the maximum alpha predicate value of the inappropriate decision is $\alpha = 0$ then,

$\mu_K = \max(\mu_K\ Feasible \cap \mu_K\ Not\ Feasible)$
$\mu_K = \max(0.33\ ;\ 0.00)$
$\mu_K = 0.33$

The defuzzification process uses the centroid method, where to determine the crisp Z value, one part can be seen in Figure 2. The section is calculated the area and moment of the membership value. The results of the defuzzification calculation are as follows:

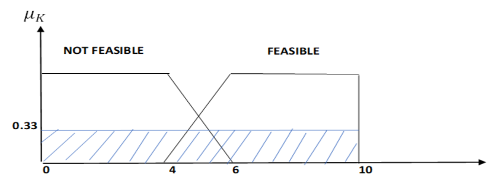


Figure 2. Defuzzification

$$Z_0 = \frac{\int_a^b Z.\mu(z)dz}{\int_a^b \mu(z)dz}$$

$$M_1 = \int_0^{10} 0.33\, z\, dz = 0.165\, z^2 \Big|_0^{10} = 0.165(10^2) = 16.5$$

$$A_1 = \int_0^{10} 0.33\ dz = 0.33\, z \Big|_0^{10} = 0.33(10) = 3.3$$

Based on these calculations, the center point of the fuzzy area is obtained, namely:

$$z = \frac{16.5}{3.3}$$

$$z = 5$$

The result of the defuzzification calculation of the Z value is 5. Based on the decision table, the value of 5 is in a feasible decision. Then employee X7 deserves a raise.

3.2 Discussion

The application of the Mamdani method based on fuzzy grid partitions begins with the formation of a fuzzy set according to the number of grid partitions or K=2. A total of 18 rules on the implication function get the minimum predicate alpha value for each decision. The rule composition is determined by choosing the maximum value of the feasible and infeasible decisions, where the predicate alpha value for the feasible decision is $\alpha = 0.33$ and the maximum alpha predicate value of the inappropriate decision is $\alpha = 0$. The result of the defuzzification calculation with the rule composition of the maximum predicate alpha value is Z = 5.

4. CONCLUSION

The application of the Mamdani method based on fuzzy grid partition results in a decision to determine the feasibility of increasing the salary of the employees of the North Sumatra Blind Foundation according to the specified attribute conditions or criteria. Application of the method results in a feasible or infeasible decision. The results of applying the method to employee X7 with a value of Z = 5 are in the feasible decision variable.

The Mamdani method based on fuzzy grid partition produces optimal output in decision making. This method can be used to solve various optimization problems. As a suggestion for future research development, the number of partitions can be increased by K=3 or K=4.

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