

INTERNATIONAL JOURNAL ON INFORMATICS VISUALIZATION

journal homepage: www.joiv.org/index.php/joiv

The Comprehensive Mamdani Inference to Support Scholarship Grantee Decision

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Abstract— Fuzzy Mamdani has been mostly used in various disciplines of science. Its ability to map the input-output in the form of a surface becomes an interesting thing. This research took DSS case of a scholarship grantee. Many criteria in taking a decision need to be simplified so that the result obtained remains intuitive. The model completion by conducting two stages consisted of two phases. The first phase consists of four FIS blocks. The second phase consists of one FIS block. The FIS design in the first phase was designed in such a way so that the output obtained has a big score interval. FIS output at the first phase will become FIS input at the second phase. This big value range becomes good input at FIS in the second phase. Each FIS block has different total input. Until the surface formed must be seen from various dimensions to assure trend surface form. The output dots change influenced by the membership function, the regulations used, total fuzzy set, and parameter value of membership function. This research used the Gaussian membership function. The Gaussian membership function is highly suitable for this DSS case. This article also explains the usage of a fuzzy set in each input, the parameter from the membership function, and the input value range. After observing the surface form with an intuitive approach, then this model needs to be evaluated. The evaluation was done to measure the model performance using Confusion Matrix. The result of model performance obtained accuracy in the amount of 85%.

Keywords-Fuzzy; mamdani; DSS; scholarship; reasoning.

Manuscript received 19 Nov. 2020; revised 30 Dec. 2020; accepted 5 Mar. 2021. Date of publication 30 Jun. 2021. International Journal on Informatics Visualization is licensed under a Creative Commons Attribution-Share Alike 4.0 International License.



I. INTRODUCTION

Mamdani inference is one of the Fuzzy Logic methods. This method has been widely used in DSS. The unique feature of this method is that it can accept linguistic variables, implement human knowledge and have the ability to make complex models that are easy to understand [1]. The cases that resolved in this study were the Scholarship Grantee. The scholarship aims to increase access and opportunities to study in higher education; improve student achievement; ensure the continuity of student studies in a timely manner; and produce graduates who are independent, productive, and have social concerns so that they can play a role in breaking the chain of poverty and empowering the community.

Other efforts that were conducted to support the program include compiling a database of secondary education level students who have good academic potential and are economically incapable of being accessed by various parties who are expected to help or provide tuition assistance [2]. This form indicates the government's effort to provide scholarships for students who cannot have academic achievements. Therefore, the selection of scholarship grantees must be under procedures, hoping that this scholarship grantee is right on target and the selection process runs objectively. Usually, scholarship applicants from year to year increase sharply. Lots of data can be easily resolved by modeling a system that adopts human knowledge.

One of the information technology systems that can help managerial decisions is to use a decision support system (DSS) [3]. Solving problems with this DSS has developed a lot [4], [5]. One of them is the Fuzzy Inference System method, both Mamdani and Tsukamoto [6] and Sugeno [7]. This fuzzy method is reliable enough to be used in various fields, including aerospace, automotive, control [8], prediction [9], [10], and informatics. Although the type-2 fuzzy [11] has been popular since the 2000s, this method in the DSS field still needs more consideration. This is due to the high cost in implementing type-2 fuzzy [12], [13] both in terms of a fairly long processing time and high computational resource requirements. So that people still use the fuzzy type-1 model in some cases. Therefore, building this DSS requires speed in producing decision recommendations. Thus, this research was designed using the type-1 fuzzy method. This research aimed to design a system that can be used in making decisions for prospective scholarship grantees.

II. MATERIAL AND METHOD

There are several fuzzy inference techniques, namely Mamdani, Stukamoto, and Sugeno. Dealing with the case of SPK, it was a more suitable solution approach using Mamdani inference. According to Jang *et al.* [14], the Fuzzy Inference System (FIS) is a computer paradigm that involves fuzzy set theory if-then rules and reasoning.

If- then, the rule of If is also known as fuzzy rules, fuzzy implication, or fuzzy conditional statements. This leads to fuzzy logic being meaningful. An example of a simple if-then rule is as follows:

If x is A then y is B
$$(1)$$

Where A and B are linguistic values expressed in fuzzy sets in ranges, X and Y. Part A is called a condition (antecedent) while part B is called a consequent.

The reasoning technique is also called the reasoning technique. The reasoning technique is a problem-solving technique by representing the problem into a knowledge base using logic. Fuzzy logic (cryptic logic) is one of the logics used in reasoning techniques [15].



Fig.1 Inference by using the method of Mamdani [14]

The process of designing this fuzzy model is still being carried out by trial and error [1]. Several processes need to be considered when designing the Mamdani fuzzy model.

- a) Select input and output variables. Based on the decision criteria.
- b) Determine the number of linguistic terms for each input and output. This can be undertaken by clustering techniques using k-means or silhouette [16], [17].
- c) Choose the type of membership function.
- d) Select parameter values for each membership function.
- e) Design the rule base.
- f) Adjust parameter value [12].

g) Analyze the formed surface. If there is no ideal surface[18], repeat from point b.

In this system, there were two applications; the first was data validation used the web, and the second was visitation used android. The system design scheme can be seen in fig.2. Operators retrieved files from the Belmawa Ristekdikti website. The file was imported to the information system for data validation. The rules regarding scholarship registration were contained in the 2019 Bidikmisi scholarship registration guide document [2].



Fig.2 System Schematic

There are 10 input criteria for consideration in choosing the Bidikmisi scholarship. The requirements can be seen in fig 3. The 10 criteria were divided into five system blocks consisting of two phases. Each block used the Type-1 Fuzzy Inference System approach. The first phase consisted of four blocks, including Academic, Economic, Household, and Coverage area. The four blocks issued output. The output became input in the second phase. The second phase carried out a fifth block process, and it was called a decision. The results of the decision block gained the output in the form of a firm value. The firm value will be ranked from the highest score.



Fig.3 Framework DSS by using Fuzzy.

All blocks used a gaussian membership function. The Gaussian membership function was determined by two parameters $\{c, \sigma\}$. The parameter of c determines the center of the Gaussian membership function, while σ determines the width of the membership function. Equation of the Gaussian membership function at eq 2 [14]

$$gaussian(x; c, \sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2}$$
(2)

The following describes the design of each block. Each block describes the input, output, knowledge, and surface. Previous studies discussed tuning on the input and output parameters. The parameter range is adjusted according to the actual data to obtain strong firm values [13]. Meanwhile, to get the form of surface that is under people's perceptions, it is necessary to optimize the rule base and its membership function [19].

A. FIS Academic

There are two (2) inputs, namely Assessment and Achievement. In fig 4 (a, b, c) can be seen the linguistic function on the academic block. Table 1 presents the inputoutput variables, the fuzzy set and its parameters.



Fig 4. Variable on academic block along with surface

TABLE I	
FIS ACADEMIC LINGUISTICS	

Variable	Fuzzy Set	Parameter
Input: Average assessment	Low	(6.5 60)
Range (60-100)	Medium	(573)
	High	(5 85)
	Very high	(8 100)
Input: Achievement	Few	(20)
Range (0-5)	Many	(25)
Output: Academic	Very low	(120)
Range (0-100)	Low	(12 25)
	Medium	(12 50)
	High	(12 75)
	Very high	(12 100)

RULE BASE OF ACADEMIC

No	Average	Achievement	Academic
	Assessment		
1	Very high	Many	Very high
2	Very high	Few	High
3	High	Many	High
4	High	Few	Medium
5	Medium	Many	High
6	Medium	Few	Low
7	Low	Many	Low
8	Low	Few	Very low

B. FIS Economics

There are two (2) inputs in the FIS Economic, namely Income and Dependent and one output can be seen in fig.5. Table 3 contains the information of fuzzy set and table 4 consists of knowledge.



Fig. 5 Variable on economic block and surface

TABLE III FIS ECONOMIC LINGUISTICS

Fuzzy Set	Parameter
Low	(6e+05 0)
Medium	(6e+05 2e+06)
High	(6e+05 4e+06)
Few	(3.25 0)
Medium	(2 6.5)
Many	(3.25 13)
Very low	(12 0)
Low	(12 25)
Medium	(12 50)
High	(12 80)
Very high	(12 100)
TABLE IV	(12 100)
	Fuzzy Set Low Medium High Few Medium Many Very low Low Medium High Very high TABLE IV

No	Income	Dependent	Economy
1	Low	Few	Low
2	Low	Medium	Very low
3	Low	Many	Very low
4	Medium	Few	High
5	Medium	Medium	Medium
6	Medium	Many	Low
7	High	Few	Very high
8	High	Medium	High
9	High	Many	Medium

C. FIS Household

There are four (4) suggestions of FIS Household, namely Homeowner, Sanitation, Marital Status and Source water which can be seen in fig.6. and one output.



Fig.6 Variable on the household block



The fuzzy set in this block can be seen in table 5 below. And table 6 contains information about knowledge.

TABLE V LINGUISTIC OF FIS HOUSEHOLD

Variable	Fuzzy Set	Parameter	
Input 1: Homeowner	Have	(35 0)	
Range (0-100)	No have	(35 100)	
Input 2: Sanitation	Good	(35 0)	
Range (0-100)	Poor	(35 100)	
Input 3: Marital	Complete	(25 0)	
Range (0-100)	Not complete	(40 100)	
Input 4: Source water	Good	(35 0)	
Range (0-100)	Not good	(35 100)	
Output: Household	Established	(20 0)	
Range (0-100)	Less established	(20 50)	
	Not Established	(20 100)	
TABLE VI RUI EBASE OF HOUSEHOLD			

No	Home	Sanita	Marital	Source	Household
110	Owner	tion	Status	Water	Household
1	Have	Good	Complete	Good	Established
2	Have	Good	Complete	Poor	Less established
3	Have	Good	Incomplete	Good	Less established
4	Have	Good	Incomplete	Poor	Not established
5	Have	Poor	Complete	Good	Less established
6	Have	Poor	Complete	Poor	Less established
7	Have	Poor	Incomplete	Good	Not Established
8	Have	Poor	Incomplete	Poor	Not Established
9	No Have	Good	Complete	Good	Less established

10	No Have	Good	Complete	Poor	Less established
11	No Have	Good	Incomplete	Good	Not Established
12	No Have	Good	Incomplete	Good	Not
13	No Have	Poor	Complete	Good	Less
14	No Have	Poor	Complete	Poor	Not Established
15	No Have	Poor	Incomplete	Good	Not
16	No Have	Poor	Incomplete	Poor	Not Established

D. FIS Coverage

There are two (2) inputs, namely land area and building area and one output shown in fig.8. while table 7 information about fuzzy sets and table 8 information about its knowledge.

TABLE VII LINGUISTIC OF FIS COVERAGE				
Variable	Fuzzy Set	Parameter		
Input 1: Land	Big	(35 0)		
Range (0-100)	Small	(35 100)		
Input 2: House	Big	(35 0)		
Range (0-100)	Small	(35 100)		
Output: Area	Small	(27 0)		
Range (0-100)	Medium	(15 50)		
	Big	(27 100)		



Fig.8 Variable block coverage

TABLE VIII LINGUISTIC OF FIS COVERAGE

No	Surface Land	Surface House	Surface Area
1	Small	Small	Small
2	Big	Big	Big
3	Small	Big	Medium
4	Big	Small	Medium

E. FIS Final DSS

The previous FIS output is an input for this FIS DSS. There are four (4) inputs, namely academic, economic, household, area. It can be seen in fig.9.





The fuzzy set in this block is in Table 9 and the knowledge information is in Table 10.

TABLE IX LINGUISTIC OF FIS FINAL DSS

Variable	Fuzzy Set	Parameter
Input 1: Academic	Low	(20 0)
Range (0-100)	Medium	(20 50)
	High	(20 100)
Input 2: Economic	Low	(20 0)
Range (0-100)	Medium	(20 50)
	High	(20 100)
Input 3: Household	Established	(20 0)
Range (0-100)	Less established	(20 50)
	Not established	(20 100)
Input 4: Area	Big	(25 0)
Range (0-100)	Medium	(20 50)
	Small	(25 100)
Output: Decision	Very low	(80)
Range (0-100)	Low	(12 20)
	Medium	(12 50)
	High	(12 80)
	Very high	(10 100)

TABLE X Rule Base fis final dss

N		Ante	ecedent		Consequent
INO	Academic	Economic	Household	Area	Decision
1	High	Low	Not established	Big	Very high
2	High	Low	Not established	Small	Very high
3	High	Low	Less established	Big	Very high
4	High	Low	Less established	Small	Very high
5	High	Low	Established	Big	Very high
6	High	Low	Established	Small	Very high
7	High	Medium	Not established	Big	High
8	High	Medium	Not established	Small	High
9	High	Medium	Less established	Big	High
10	High	Medium	Less established	Small	High
11	High	Medium	Established	Big	Medium
12	High	Medium	Established	Small	Medium
13	High	High	Not established	Big	Medium

14	High	High	Not established	Small	Medium
15	High	High	Less established	Big	Low
16	High	High	Less	Small	Low
17	High	High	Established	Big	Low
18	High	High	Established Not	Small	Low
19	Medium	Low	established	Big	High
20	Medium	Low	Not established	Small	High
21	Medium	Low	Less established	Big	High
22	Medium	Low	Less established	Small	High
23	Medium	Low	Established	Established Big	
24	Medium	Low	Established	Small	Medium
25	Medium	Medium	Not established	Big	High
26	Medium	Medium	Not established	Small	High
27	Medium	Medium	Less established	Big	High
28	Medium	Medium	Less established	Small	High
29	Medium	Medium	Established	Big	Medium
30	Medium	Medium	Established	Small	Medium
31	Medium	High	established	Big	Medium
32	Medium	High	Not established	Small	Medium
33	Medium	High	Less established	Big	Low
34	Medium	High	Less established	Small	Low
35	Medium	High	Established	Big	Very low
36	Medium	Hıgh	Established	Small	Very low
37	Low	Low	established	Big	Low
38	Low	Low	established	Small	Low
39	Low	Low	Less established	Big	Low
40	Low	Low	Less established	Small	Low
41	Low	Low	Established	Big	Low
42	Low	Low	Established	Small	Low
43	Low	Medium	established	Big	Low
44	Low	Medium	established	Small	Low
45	Low	Medium	Less established	Big	Low
46	Low	Medium	Less established	Small	Low
47	Low	Medium	Established	Big	Very low
48	Low	Medium	Established	Small	Very low
49	Low	High	Not established	Big	Very low
50	Low	High	Not established	Small	Very low
51	Low	High	Less established	Big	Very low
52	Low	High	Less established	Small	Very low
53	Low	High	Established	Big	Very low
54	Low	High	Established	Small	Verv low

III. RESULT AND DISCUSSION

A good surface is formed from a smoother movement of output points. As shown in figure fig.4 (d), fig.5 (d), fig.8 (d), there is no significant gap. The Input-Output surface (I/O surface) is easy to be observed because the mapping is still in 3-dimensional space. Another description of the surface in the picture of fig.7, the mapping of input-output produces 5 dimensions where there are 4 inputs and 1 output. Due to human limitations in modeling space so that the resulting surface remains in 3 dimensions. Mapping of two inputs and one output while the other 2 inputs are made constant. From the I / O surface results that were formed, it was still visible that the gaps were formed. A lot of inputs probably caused this, and each input had a little fuzzy set. The surface was still acceptable because the trend was still visible, whether it is decreasing or increasing.

The results presented were taken from FIS academic and FIS economic. Both of these FIS greatly influenced the final DSS results. This was due to the design of academic and economic outputs where there were many fuzzy sets. This firm output in phase 1 makes the value range large. This will be profitable as an input in phase 2. The FIS economy had the lowest value of 15.49, and the highest value was 71.14. while FIS academic had the highest value of 71.94 and the lowest was 16.38. FIS economic output showed that the income was small or dependent a lot, got a low economic value. This can be seen in table 11. Likewise, with FIS academic, high values, or many achievements, the academic values will be high, as shown in table 12.

TABLE XI The Output of FIS Economic

Name	income	dependent	Out economic
Student 21	0	3	15.49
Student 27	750000	6	19.38
Student 22	0	2	22.10
Student 17	500000	3	22.57
Student 11	0	1	25.79
Student 15	500000	2	26.06
Student 14	750000	5	27.08
Student 7	750000	4	28.61
Student 6	1250000	5	31.85
Student 3	1000000	5	34.10
Student 19	1000000	5	34.10
Student 1	750000	2	34.25
Student 18	750000	3	35.06
Student 26	750000	3	35.06
Student 29	750000	3	35.06
Student 23	1000000	4	38.96
Student 5	3000000	6	39.01
Student 24	3000000	6	39.01
Student 16	1500000	4	40.78
Student 28	1500000	4	40.78
Student 9	3000000	5	45.49
Student 20	1000000	2	50.00
Student 12	2000000	3	50.03
Student 13	1750000	3	50.03
Student 10	1500000	3	50.03
Student 2	1250000	2	58.92
Student 8	1250000	2	58.92
Student 25	1500000	2	60.10
Student 4	2250000	2	60.53
Student 30	3500000	3	71.14

OUTPUT FIS ACADEMIC							
Name	Assessment	Achievement	Out Academic				
Student 1	92.53571	2	71.94				
Student 8	89.53571	2	69.69				
Student 15	87	2	68.23				
Student 6	90.28571	1	58.69				
Student 2	91.10714	0	52.26				
Student 3	91.03571	0	52.11				
Student 4	90.96429	0	51.97				
Student 5	90.46429	0	50.90				
Student 29	90	0	49.80				
Student 7	89.97569	0	49.74				
Student 21	84.60714	1	49.16				
Student 30	85	1	49.16				
Student 9	89.46429	0	48.36				
Student 10	89.28571	0	47.82				
Student 11	89.17857	0	47.49				
Student 27	88	0	43.21				
Student 12	87.57143	0	41.36				
Student 13	87.42857	0	40.76				
Student 14	87.17857	0	39.77				
Student 16	86.78571	0	38.12				
Student 17	86.45833	0	36.67				
Student 18	85.82143	0	34.13				
Student 19	85.71429	0	33.75				
Student 20	84.72222	0	30.88				
Student 26	84	0	29.49				
Student 22	81.92857	0	28.29				
Student 23	81	0	27.95				
Student 24	80.52256	0	27.71				
Student 28	78	0	23.75				
Student 25	75	0	16.38				

TABLE XII

In table 13, the results data are sorted based on the highest decision value. The highest decision value is obtained by student 21. Student 21 has the lowest economic value and average academy value. Student 15 has low economic value and somewhat high academic values. And student 27 has the two lowest economic grades and average academic values. Note that students 15 and 27 have almost the same assessment values, but it is far different academic values. The academic value of student 15 is 68.23, while the academic value of student 27 is 43.21. This is because student 15 has some achievement while student 27 has no achievement. By looking at this phenomenon, problem-solving uses fuzzy under human perception. This human perception is also related to instinct. In AI, this fuzzy system can be created intuitively.

TABLE XIII OUTPUT DSS

Name					
	Out economy mic	Out Academic	Out Household	Out Area	Out Decision
Student 21	15.49	49.16	62.86	42.97	68.82
Student 15	26.06	68.23	48.54	58.90	62.49
Student 27	19.38	43.21	75.01	28.22	62.17
Student 11	25.79	47.49	65.99	49.38	61.05
Student 1	34.25	71.94	50.62	21.74	60.90
Student 7	28.61	49.74	50.62	31.35	59.37
Student 17	22.57	36.67	59.49	74.30	59.00
Student 6	31.85	58.69	50.62	58.90	57.91
Student 14	27.08	39.77	75.01	21.74	57.82
Student 3	34.10	52.11	78.95	42.97	56.57
Student 8	58.92	69.69	50.62	42.97	55.74
Student 29	35.06	49.80	50.52	21.74	55.20
Student 5	39.01	50.90	50.52	49.38	53.11
Student 22	22.10	28.29	75.01	28.22	51.84
Student 9	45.49	48.36	75.01	42.97	50.85
Student 19	34.10	33.75	59.49	51.34	49.80
Student 10	50.03	47.82	48.54	40.15	49.63
Student 18	35.06	34.13	62.86	28.22	49.44
Student 16	40.78	38.12	50.62	58.90	48.93
Student 2	58.92	52.26	48.54	40.15	48.22
Student 12	50.03	41.36	48.54	22.88	47.64
Student 4	60.53	51.97	50.60	49.38	47.54
Student 13	50.03	40.76	48.54	22.88	47.40
Student 26	35.06	29.49	50.61	42.97	46.67
Student 24	39.01	27.71	50.52	51.34	43.37
Student 23	38.96	27.95	72.56	21.74	43.12
Student 20	50.00	30.88	62.86	22.45	42.15
Student 30	71.14	49.16	50.52	22.45	40.64
Student 28	40.78	23.75	50.61	22.88	39.34
Student 25	60.10	16.38	50.62	51.34	31.69

Measurement of model performance using a confusion matrix. Model accuracy can use the formula [20]:

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN} * 100\%$$
(3)

Notes: TP: True Positive

TN: True Negative

- FP: False Positive
- FN: False Negative

Model accuracy is obtained by comparing the results of the fuzzy system with manual results. The results obtained show that the system accuracy reaches 85%.

IV. CONCLUSION

In designing the input-output, it must attempt to minimize the ideal number of inputs is 2 input 1 output. By having 2 inputs, it can facilitate the researcher to observe the surface that is formed. The smoother the surface that is formed, the more human the decisions will be obtained. The evaluation of the model using a confusion matrix obtained an accuracy rate of 85%. The suggestion for future research is the significance of software that can help the researcher to get more optimal fuzzy and rule base sets.

ACKNOWLEDGMENT

We are grateful to the Ministry of Research, Technology, and Higher Education for funding this research with contract number 045 / PL9.1.4 / PP / 2019.

REFERENCES

- P. Georgieva, "Fuzzy Rule-Based Systems for Decision-Making," no. May 2016, 2018.
- [2] S. D. A. N. Sbmptn, "Panduan pendaftaran beasiswa bidikmisi 2019," 2019.
- [3] E. Turban, J. E. Aronson, and T.-P. Liang, "Decision Support Systems and Business Intelligence," Decis. Support Bus. Intell. Syst. 7/E, pp. 1–35, 2007, doi: 10.1017/CBO9781107415324.004.
- [4] S. G. Fashoto, O. Amaonwu, and A. Afolorunsho, "Development of A Decision Support System on Employee Performance Appraisal using AHP Model," JOIV Int. J. Informatics Vis., vol. 2, no. 4, p. 262, 2018, doi: 10.30630/joiv.2.4.160.
- [5] Z. T. Al-Ars and A. Al-Bakry, "A web/mobile decision support system to improve medical diagnosis using a combination of K-mean and fuzzy logic," Telkomnika (Telecommunication Comput. Electron. Control., vol. 17, no. 6, pp. 3145–3154, 2019, doi: 10.12928/Telkomnika.v17i6.12715.
- [6] C. B. M. T. Xyz, "Funding Eligibility Decision Support System Using Fuzzy Logic Tsukamoto," no. March 2018, 2017, doi: 10.1109/IAC.2017.8280622.
- [7] M. Blej and M. Azizi, "Comparison of Mamdani-type and Sugenotype fuzzy inference systems for fuzzy real time scheduling," Int. J. Appl. Eng. Res., vol. 11, no. 22, 2016.
- [8] A. Hidayat and D. Putra, "Temperature and Soil Control Design with Fuzzy Method in Greenhouse for Cabe Seeding," vol. 3, pp. 243–247.
- [9] M. N. Shodiq, D. H. Kusuma, M. G. Rifqi, A. R. Barakbah, and T. Harsono, "Adaptive Neural Fuzzy Inference System and Automatic Clustering for Earthquake Prediction in Indonesia," JOIV Int. J. Informatics Vis., vol. 3, no. 1, pp. 47–53, 2019, doi: 10.30630/joiv.3.1.204.
- [10] T. Tung Khuat and M. H. Le, "An Application of Artificial Neural Networks and Fuzzy Logic on the Stock Price Prediction Problem," JOIV Int. J. Informatics Vis., vol. 1, no. 2, p. 40, 2017, doi: 10.30630/joiv.1.2.20.
- [11] J. M. Mendel, "Introduction to Type-2 Fuzzy Sets and Systems I. Type-2 Fuzzy Sets Especially Interval Type-2 Fuzzy Sets What is a T2 FS and How is it Different From a T1 FS ?"
- [12] W. Mendes, "Comparison of Fuzzy Type-2 and Conventional Fuzzy Controllers Tuned by Ant Colony Optimization," no. January 2017, doi: 10.26678/ABCM.COBEM2017.COB17-1934.
- [13] I. Rahmayuni, "Tuning Parameters On Fuzzy Inference Based Decision Support System," 2018 Int. Conf. Appl. Sci. Technol., pp. 35–38, 2018, doi: 10.1109/iCAST1.2018.8751539.
- [14] J.-S. R. Jang, C.-T. Sun, and E. Mizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence. 1997.
- [15] L. A. Zadeh, "Fuzzy Logic," Computer (Long. Beach. Calif)., vol. 21, no. 4, pp. 83–93, 1988, doi: 10.1109/2.53.
- [16] P. N. Padang, "Determining the Appropriate Cluster Number Using Elbow Method for K-Means Algorithm," 2018, doi: 10.4108/eai.24-1-2018.2292388.
- [17] T. M. Kodinariya and P. R. Makwana, "Review on determining number of Cluster in K-Means Clustering," Int. J. Adv. Res. Comput. Sci. Manag. Stud., vol. 1, no. 6, pp. 2321–7782, 2013.
- [18] K. P. Chiao, "The multi-criteria group decision making methodology using type 2 fuzzy linguistic judgments," Appl. Soft Comput. J., vol. 49, 2016, doi: 10.1016/j.asoc.2016.07.050.
- [19] P. N. Padang, P. N. Padang, and P. N. Padang, "Designing Mamdani Fuzzy Inference Systems for Decision Support Systems," no. 1, pp. 111–115, 2019.
- [20] F. Gorunescu, Data Mining concepts, Models and Techniques. Springer, 2011.