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Study and Implementation of the Fuzzy Mamdani and Sugeno Methods in Decision Making on Selection of Outstanding Students at the South Aceh Polytechnic

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ABSTRACT

The selection of students who excel academically is a measure of education quality in an educational institution. In the implementation of education, student achievement becomes a measure of academic success at the institution. Achievement results from hard work by following the rules given by a particular person or institution with specific criteria and conditions to determine if someone is eligible to be chosen as an award recipient. This research uses the Mamdani Fuzzy method or Fuzzy inference system. Sugeno Fuzzy designed this decision-making system to develop the decision results from the rules compiled using Matlab software for testing. The South Aceh Polytechnic holds special student elections every year. The selection of students with achievements that are carried out every year only focuses on the GPA value in academic achievement without looking at the determining factors which are more precise. In the research that will be conducted, the selection must meet the eligibility criteria as a student who gets an award or as an outstanding student at the South Aceh Polytechnic involving variables in the Cumulative Achievement Index, Final Project value, Extracurricular, and Attendance. Research is expected to be a tool in the selection process for candidate participants who complete the selection of outstanding students at the South Aceh Polytechnic. So, relevant departments in universities can determine the eligibility of prospective students as award recipients as students with the best achievement scores by considering the relevant determining factors. The expected output using the Mamdani and Sugeno fuzzy method can become an intellectual property system. This system can be selected as a guideline by the South Aceh Polytechnic academic for determining outstanding students. The research results show that the level of truth is 86.82% for the Mamdani method, while the implementation of Sugeno Fuzzy logic is obtained a level of reality of 71.88%.

I. Introduction

The selection of students who excel academically is a measure of education quality in an educational institution [1]. Achievement results from hard work by following the rules given by a person or institution with specific criteria to determine if someone deserves to be selected as an award recipient. If it is related to higher education, the achievement is when a student can excel in college and other academic skills, which are the determining variables for the student being selected as the student with the best academic achievement [2]. In a study conducted by Laras Purwati Ayuningtias et al. To predict the number of new students in the following year by looking at the number of new students in the previous year, this study uses three fuzzy methods, namely Tsukamoto, Sugeno, and Mamdani fuzzy. The research that has been done obtained the error rate of each way, where the Mamdani Fuzzy method error is 19.76%, Tsukamoto Fuzzy is 39.03%, and Fuzzy Sugeno is 86.41% [3]. Dorteus Lodewyik Rahakbauw also conducted this research using the

Fuzzy Sugeno method. His research on determining the amount produced by a bakery based on the production of the amount of demand and inventory data helped determine the factory's amount of bread. The results obtained a truth level of 86.92165% [4].

Furthermore, research conducted by Eka Mahargiyak et al. Regarding the application of the Sugeno method of Fuzzy Logic for Weather Forecasting Decision Support Systems, this study directs to be able to do weather forecasts by implementing the Sugeno Fuzzy process and can also see and calculate the level of accuracy of the data from the research results. The results show that manual data verification tests and system verification in the excellent category, where manual data verification was 76%, and system data verification tests were 74% [5].

Based on other researchers' research related to decision-making systems, the decisions taken must meet the eligibility criteria as outstanding students for the study to be conducted. Therefore, the South Aceh Polytechnic College, a three-year diploma that produces graduates with skills and skills, is held annually to select outstanding students for those who have completed semester VI (six) and only those who can complete studies for 3 (three) years. The selection of exceptional students is based on the GPA score without looking at other more precise variables, such as non-academic student activities or even collecting several assessment items and determining the average number of the determined items so that each assessment's accuracy is less than optimal. In this study, the selection of high-achieving students must involve variables in the form of Grade Point Average, Final Project Value, Extracurricular, and Attendance. The results of this study serve as guidelines or aids in decision making in determining outstanding students. This decision-making system is designed using tools in the form of a Graphic User Interface (GUI) in Matlab.

II. Theoretical Background

2.1 Fuzzy Logic or Fuzzy Inference System

Fuzzy logic is one of the scientific fields of technology related to the formation of soft computing to sets as input variables will be designed with rules so that a decision can be taken. As illustrated in Figure 1 below:

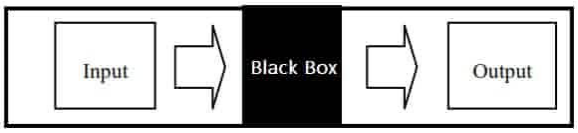


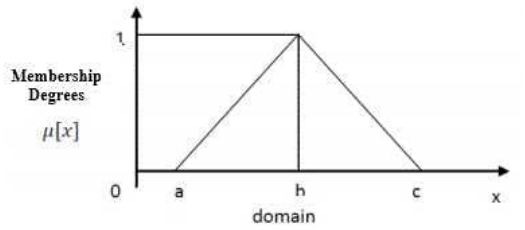
Figure 1. Mapping the input-output process in fuzzy [6]

It uses fuzzy logic to combine a broad set of fundamental indicators and then calculates a numerical value of sustainability for many hands to draw a logical conclusion [7]. As mentioned earlier, Fuzzy is a component of soft computing formation. In terms of this, Fuzzy logic can also be interpreted as a vague or vague decision. A value in this fuzzy can be either broad or false simultaneously because, in the Fuzzy term, the degree of membership has an interval of 0 (zero) to 1 (one). The person who first introduced fuzzy theories in scientific studies was Prof. Lotfi Zadeh in 1965. Prof. Lotfi Zadeh, who is currently a reference for many researchers, said that set theory plays an essential role in determining the membership function or a term known in fuzzy, namely the degree of membership [8]. The Mamdani Fuzzy method is a fuzzy inference system because the technique is a combination of each fuzzy rule. The degree of membership is calculated to be defuzzified to get the relevant results in a system [9].

This fuzzy relationship is based on addition and multiplication obtained from vague rules. This solution is offered by fuzzy logic in making decisions from a compiled law, also known as the fuzzy arithmetic model. This Fuzzy relationship turns out to be a solution to the conclusion system so that theoretical and practical results are obtained [10].

2.2 Membership Function

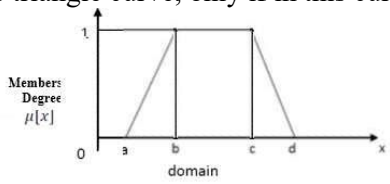
The membership function is a curve that shows the mapping of data input points into its membership value or the degree of membership. This degree of membership has a value range from 0 to 1 [8]. There are several membership functions, such as triangle curve representation and trapezoidal curve representation.



$$\mu[x] = \begin{cases} 0; & x \le a \ \ or \ \ x \ge c \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{b-x}{c-b} & x \ge 60 \end{cases} \quad (1)$$

Figure 2. Triangle Curve

Furthermore, the implantation of the trapezoid curve is a combination of the representation of the triangle curve, only if in this curve, some member values are 1.



$$\mu[x] = \begin{cases} 0; & x \le a \ \ or \ \ x \ge d \\ \dfrac{x-a}{b-a}; & a \le x \le b \\ 1; & b \le x \le c \\ \dfrac{d-x}{d-c} & x \ge d \end{cases} \quad (2)$$

Figure 3. Trapezium curve

2.3 Fuzzy Mamdani

Mamdani Fuzzy logic is a scientific theory known as Max-Min. The first time to introduce this theory was Ebrahim Mamdani in 1975. The fuzzy Mandani started from creating fuzzy sets, designing rules that are often known as rules or other terms. Application of implication functions that become benchmarks for decision making, the composition of management, and defuzzification [11].

In the Mamdani fuzzy method, there are several steps as follows:

1. Determine the fuzzy set used
   First, determine a fuzzy set and decide what variables are included in the input and output variables.
2. Forming the implication function
   The implication function uses the AND operator or the OR operator. If using AND, then the minimum role is taken. On the other hand, if OR, the maximum function is taken, then it is connected with the THEN command for the decision to be taken, generally as follows [8]: IF (x_1 is A_1) AND (x_2 is A_2) AND (x_3 is A_3)… AND (x_n is A_n) THEN y is B.
3. Determine rules (the composition of rules)
   The composition uses the Mamdani composition or the term MAX-MIN as well.
4. Defuzzification
   Confirmation is a process of defuzzification in each set. Defuzzification is obtained from several fuzzy set variables so that it is connected to the output as the final result obtained is followed up in decision making [12].

2.4 Fuzzy Sugeno

Logical decision-making with the Sugeno method is related and close by drawing conclusions made with the Mamdani method. Mamdani's difference is only in the output where the system is not a Fuzzy set an equation or constant, a technique introduced by Sugeno Kang in 1986 [13]. This Sugeno in its membership function is in Singleton. The membership function has a membership degree of 1 at a single crisp value, while in other crisp matters is 0.

There are two parts to Sugeno's fuzzy model:

1. Zero-Order Fuzzy Sugeno Model
   The following formula is Sugeno's fuzzy form in general in Zero-Order, namely: IF (x1 is A1) • (x2 is A2) • (x3 is A3) • ..... • (xN is An) THEN z=k
   Where: Ai is the ith Fuzzy set as an antecedent (reason), and k is a constant (emphatic) as a consequence (conclusion).
2. Fuzzy Sugeno Order-1 Model
   IF (x1 is a1) ° (x2 is A2) °…°(xn is An) THEN z = p1*x1+…+pn*xn+q,

Where: Ai is the ith fuzzy set as an antecedent (reason), ° is the fuzzy operator (AND or OR), pi is the ith constant, and q is also continuous in consequence.

2.5 Decision support system

A decision support system can be a system that provides data modeling to help make a semi-structured decision. That someone will never know the pattern of decision making on decisions received from certain parties cannot be traced with certainty how to produce the decisions given [14]. In this study using Matlab software for testing, the illustration of test design as in Figure 4 below:

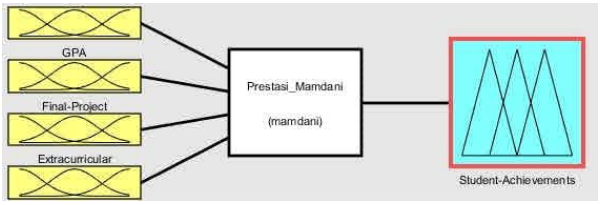


Figure 4. Design using Matlab

In Figure 4 above, the flow of decision making using the fuzzy method is to collect input variables then compile rules to get the final decision. The compilation of the number of rules uses the permutation formula. The permutation is a system of compiling a set of objects arranged in an order that is different from one another without any repetitive arrangements because the permutation sequence is crucial [15].

$$nPr = n^r \quad (3)$$

Where n is the number of objects that can be selected, and r is the number of items specified.

2.6 Mean Percentage Error (MPE)

After the testing process is carried out, calculating the correctness of the tests carried out is then carried out, using either the Mamdani fuzzy logic method or the Sugeno Fuzzy logic method. At the calculation stage, the truth value uses the mean percent error value known as the Mean Percentage Error (MPE) [16].

$$MPE = \frac{\sum_{t=1}^{n} \frac{(Y_t - \hat{Y}_t)}{Y_t} x\ 100\%}{n} \quad (4)$$

In this equation, t = 1 to n indicates the amount of data, Y_t is the original data, $\hat{Y}_t$ is the I observation's predicted value, and n is the amount of data.

III. Method

This research was designed by following the Mamdani and Sugeno fuzzification systems. The work system in this study is as follows:

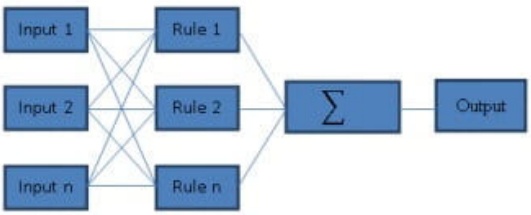


Figure 5. Research Concept Scheme

From the conceptual scheme of this research, the decision-making system is based on input variables. The rules for the testing process are carried out using the fuzzy Mamdani and Sugeno logic methods. The final result is a decision in the form of outstanding students.

The data collection method is by taking data from students in semester VI (six) who have completed three years of study for testing. Data for graduates over three years will not be processed to be included in this decision-making system. Table 1 is the sample data used.

Table 1. Testing data

No	Name of the student	Variable			
		IPK/ GPA	Final project	Extracurricular	Attendance
1	Student01	3.38	86.75	73	95.34
2	Student02	3.25	79.58	195	92.85
3	Student03	3.19	79.30	79	90.03
4	Student04	3.71	87.04	156	95.60
5	Student05	3.30	82.00	63	93.80
6	Student06	3.16	85.02	72	90.00
7	Student07	3.15	82.01	86	86.65
8	Student08	2.61	74.56	67	65.40
9	Student09	3.35	86.07	192	93.65
10	Student10	3.57	85.81	126	97.60
11	Student11	3.01	75.00	71	80.00
12	Student12	3.39	88.16	82	90.10
13	Student13	3.09	85.80	65	80.40
14	Student14	2.61	79.10	75	60.80
15	Student15	3.26	85.40	122	84.90
16	Student16	2.95	82.16	67	70.35
17	Student17	3.23	84.00	83	90.20
18	Student18	2.84	80.07	63	76.65
19	Student19	2.85	80.70	66	68.93
20	Student20	2.86	82.36	86	78.70
21	Student21	3.00	82.02	90	80.70
22	Student22	2.89	86.25	50	75.00
23	Student23	3.25	87.06	70	90.80
24	Student24	3.27	86.56	68	83.30
25	Student25	3.38	87.69	144	90.20
26	Student26	3.42	89.96	85	95.52
27	Student27	3.21	85.50	72	90.70
28	Student28	3.25	80.00	98	89.65
29	Student29	3.49	86.45	59	94.70
30	Student30	2.97	83.97	102	80.00
31	Student31	2.94	86.73	49	64.90
32	Student32	3.35	85.48	84	95.30
33	Student33	3.15	87.48	60	85.34
34	Student34	3.10	85.90	74	80.21
35	Student35	2.93	86.88	85	78.50
36	Student36	3.08	85.30	85	87.00
37	Student37	3.33	89.00	42	93.45
38	Student38	3.34	90.30	114	93.33
39	Student39	2.95	86.92	64	70.76
40	Student40	3.07	86.10	40	82.70

IV. Result And Discussion

A. Set Formation and Implication Function

The formation of this fuzzy set includes four variable parts, including the GPA, Final Project, Extracurricular, and Attendance variables. Each input variable has a linguistic function consisting of three parts: low, medium, and high. In comparison, the output variable has four linguistic functions, namely less, enough, reasonable, and best.

Table 2. Formation of fuzzy sets and their domain

Input Variable	fuzzy set		The semester of conversation
	Type	Domain	
IPK	Low	0 - 3	0 – 4
	Medium	2.5 - 3.5	
	High	3 - 4	
Final Project	Low	0 - 70	0 – 100
	Medium	60 - 90	
	High	80 - 100	
Extracurricular	Low	0 - 100	0 – 300
	Medium	50 - 200	
	High	150 - 300	
Attendance	Low	0 - 60	0 – 100
	Medium	50 - 90	

Input Variable	fuzzy set		The semester of conversation
	Type	Domain	
Output	High	80 - 100	0 – 100
	Less	0 – 30	
	Enough	20 – 60	
	Good	50 – 90	
	Best	80 - 100	

B. Application function Implication of input

The application of the implication function of each input value of each variable can be seen in Figure 6 to Figure 10.

1. Variable IPK / Grade Point Average GPA

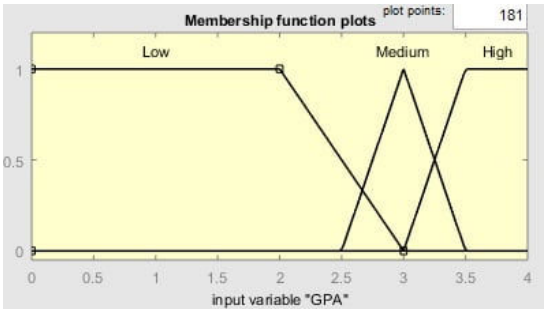


Figure 6. Application of GPA implication function

Membership function

$$\mu_{Low}[x] = \begin{cases} 1; & x \le 2 \\ \frac{3-x}{3-2} & 2 \le x \le 3 \\ 0; & x \ge 3 \end{cases} \quad (5)$$

$$\mu_{Medium}[x] = \begin{cases} \frac{x-2}{3-2} & 2 \le x \le 3 \\ 1; & x = 3 \\ \frac{3.5-x}{3.5-3} & 3 \le x \le 3.5 \end{cases} \quad (6)$$

$$\mu_{High}[x] = \begin{cases} \frac{x-3}{3.5-3} & 3 \le x \le 3.5 \\ 1; & x \ge 3.5 \end{cases} \quad (7)$$

2. Variable Final Project

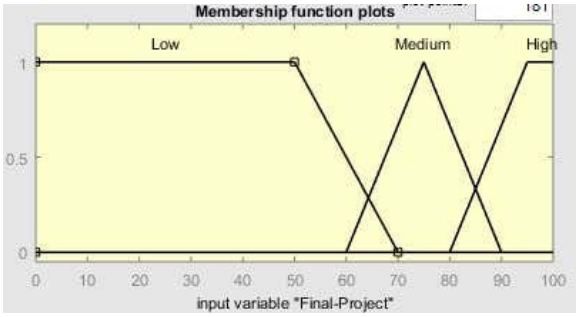


Figure 7. Application of Final Project implication function

Membership function

$$\mu_{Low}[x] = \begin{cases} 1; & x \le 50 \\ \frac{70-x}{70-50} & 50 \le x \le 70 \\ 0; & x \ge 70 \end{cases} \quad (8)$$

$$\mu_{Medium}[x] = \begin{cases} \frac{x-60}{75-60} & 60 \le x \le 75 \\ 1; & x = 75 \\ \frac{90-x}{90-75} & 75 \le x \le 90 \end{cases} \quad (9)$$

$$\mu_{High}[x] = \begin{cases} \frac{x-80}{95-80} & 80 \le x \le 95 \\ 1; & x \ge 95 \end{cases} \quad (10)$$

3. Variable Extracurricular

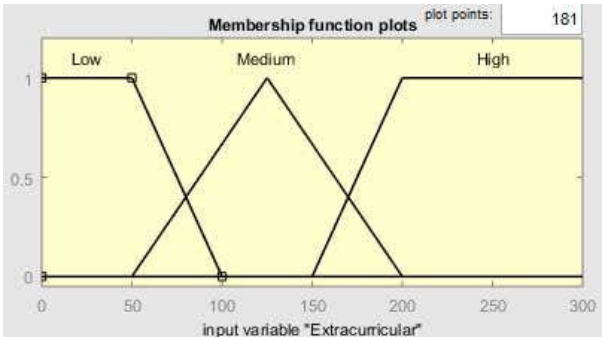


Figure 8. Application of Extracurricular implication function

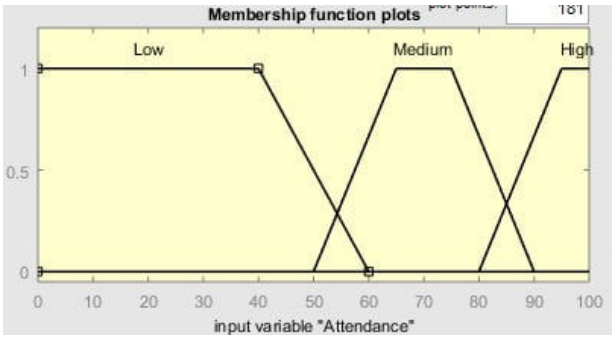
Membership function

$$\mu_{Low}[x] = \begin{cases} 1; & x \le 50 \\ \frac{100-x}{100-50} & 50 \le x \le 100 \\ 0; & x \ge 100 \end{cases} \quad (11)$$

$$\mu_{Medium}[x] = \begin{cases} \frac{x-50}{125-50} & 50 \le x \le 125 \\ 1; & x = 125 \\ \frac{200-x}{200-125} & 125 \le x \le 200 \end{cases} \quad (12)$$

$$\mu_{High}[x] = \begin{cases} \frac{x-150}{200-150} & 150 \le x \le 200 \\ 1; & x \ge 200 \end{cases} \quad (13)$$

4. Variable Attendance



Membership function

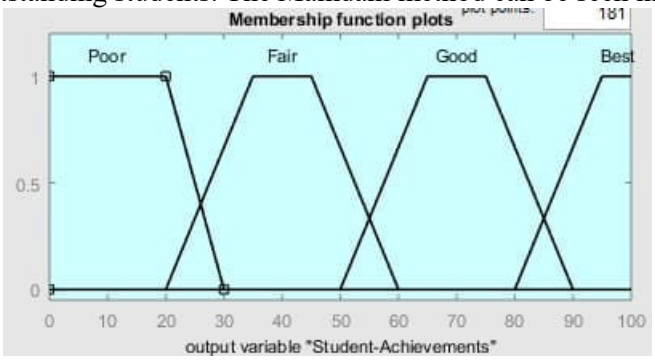
$$\mu_{Low}[x] = \begin{cases} 1; & x \leq 40 \\ \frac{60-x}{60-40} & 40 \leq x \leq 60 \\ 0; & x \geq 60 \end{cases} \quad (14)$$

$$\mu_{Medium}[x] = \begin{cases} 0 & 50 \leq x \ atau \ x \geq 90 \\ \frac{x-50}{65-50} & 50 \leq x \leq 65 \\ 1; & 65 \leq x \leq 75 \\ \frac{90-x}{90-75} & x \geq 90 \end{cases} \quad (15)$$

$$\mu_{High}[x] = \begin{cases} \frac{x-80}{95-80} & 80 \leq x \leq 95 \\ 1; & x \geq 95 \end{cases} \quad (16)$$

Figure 9. Application of Attendance implication function

The percentage value range of output from research with the Mamdani and Sugeno fuzzy methods is given the recommendation size is 0 - 100% to get the value as a participant of outstanding students. The Mamdani method can be seen in Figure 10 below:



Membership function

$$\mu_{Poor}[x] = \begin{cases} 1; & x \leq 20 \\ \frac{30-x}{30-20} & 20 \leq x \leq 30 \\ 0; & x \geq 30 \end{cases} \quad (17)$$

$$\mu_{Fair}[x] = \begin{cases} 0 & 20 \leq x \ atau \ x \geq 60 \\ \frac{x-20}{35-20} & 20 \leq x \leq 35 \\ 1; & 35 \leq x \leq 45 \\ \frac{60-x}{60-45} & x \geq 60 \end{cases} \quad (18)$$

$$\mu_{Good}[x] = \begin{cases} 0 & 50 \leq x \ atau \ x \geq 90 \\ \frac{x-50}{65-50} & 50 \leq x \leq 65 \\ 1; & 65 \leq x \leq 75 \\ \frac{90-x}{90-75} & x \geq 90 \end{cases} \quad (19)$$

$$\mu_{Best}[x] = \begin{cases} \frac{x-80}{95-80} & 80 \leq x \leq 95 \\ 1; & x \geq 95 \end{cases} \quad (20)$$

Figure 10. Application of Output implication function

The use of Mamdani and Sugeno methods is almost the same. Only the difference is in the output process. There is no classification for each value to be issued, but in Sugeno, determining the final value uses linear and constant choices. In this test using the continuous option to see the output value by taking the lowest value at the initial output in the form of a value of 0, the middle value between the initial and final values, namely, the category is entirely worth 40 and the Good type is worth 70. The absolute value is taken as the highest output value in the class for the output—best worth 100. The view can be seen in Figure 11 below.

Figure 11. Sugeno fuzzy method output

C. Fuzzy rules applied.

In this research, two methods are used: using the Mamdani fuzzy logic method and Sugeno fuzzy logic. The fuzzy rules are formulated with the fuzzy criteria Low, Enough, Medium, High. With Variable (Variable = 1,2,3,4). The number of these rules of 81 is obtained from equation (2.3). The formula used in this equation is :

$$nPr = n^r \quad (3)$$

where n is the number of objects that can be selected, and r is the number of items selected. So we get the fuzzy rule total used to be 81 rules by substituting it into the equation: $n^r = 3^4=81$.

Table 3. Fuzzy rules

No Rules	Fuzzy set				Decision (Then)
	IPK/GPA	Final Project	Extracurricular	Attendance	
1	High	High	High	High	Best
2	High	High	High	Medium	Best
11	High	Medium	High	Medium	Good
12	High	Medium	High	Low	Good
24	High	Low	Medium	Low	fair
25	High	Low	Low	High	fair
80	Low	Low	Low	Medium	Poor
81	Low	Low	Low	Low	Poor

The test results with the Graphic User Interface process with Matlab using both Mamdani and Sugeno methods can be seen in Figure 12 and Figure 13 below.

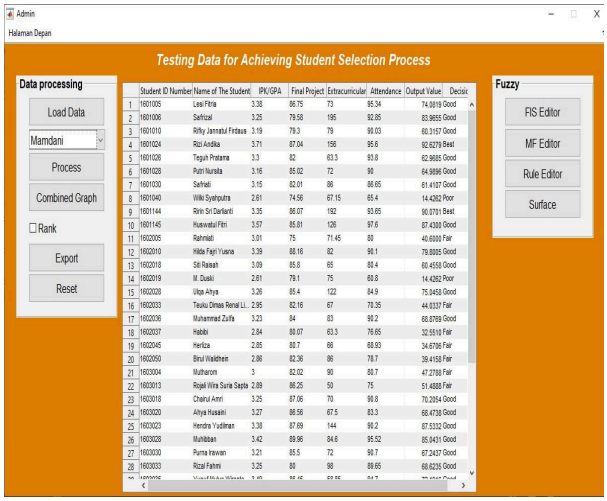


Figure 12. Testing the data of the Mamdani method

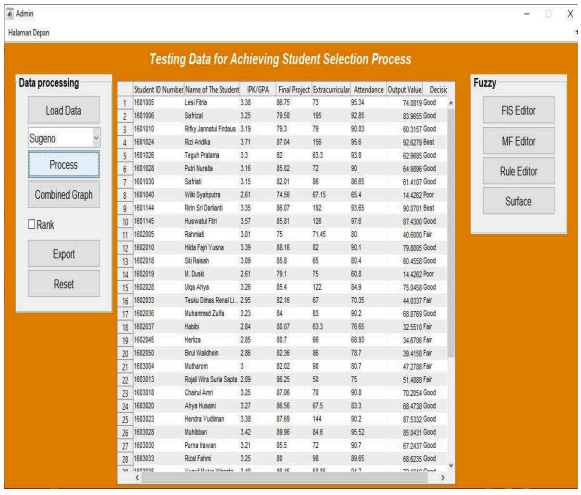


Figure 13. Testing the data of the Sugeno method

The test graph is shown in Figure 14 and Figure 15 below.

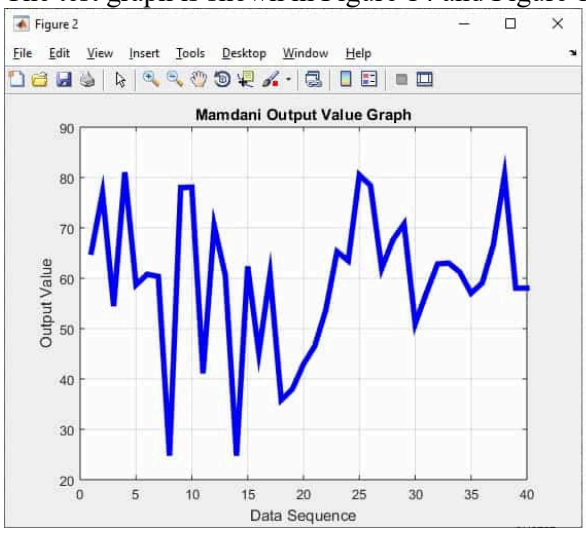


Figure 14. Graph of Mamdani data testing

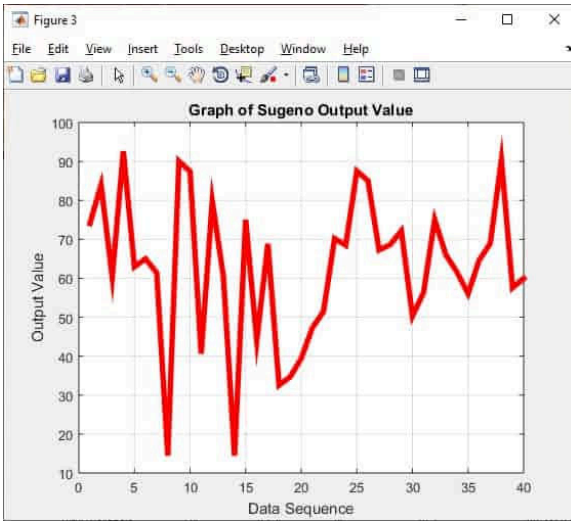


Figure 15. Graph of Sugeno data testing

The combination of the two graphs of the methods used, both the Sugeno method and the Mamdani test method, can be seen in Figure 16.

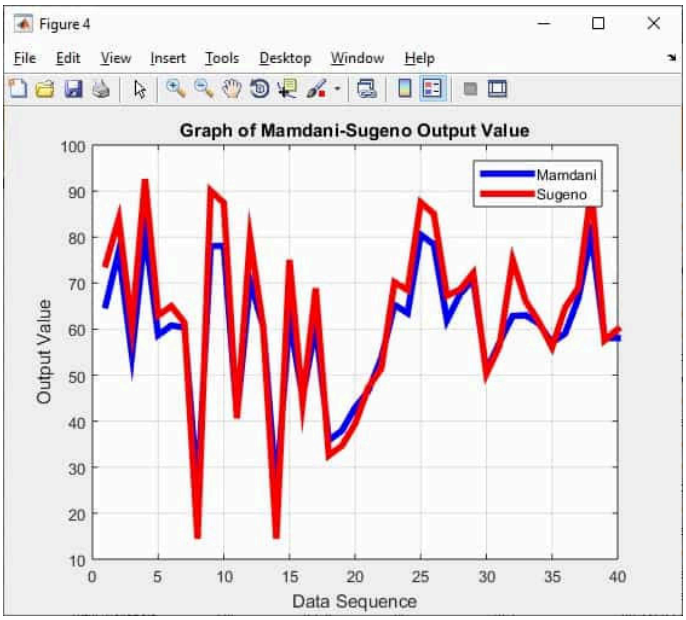
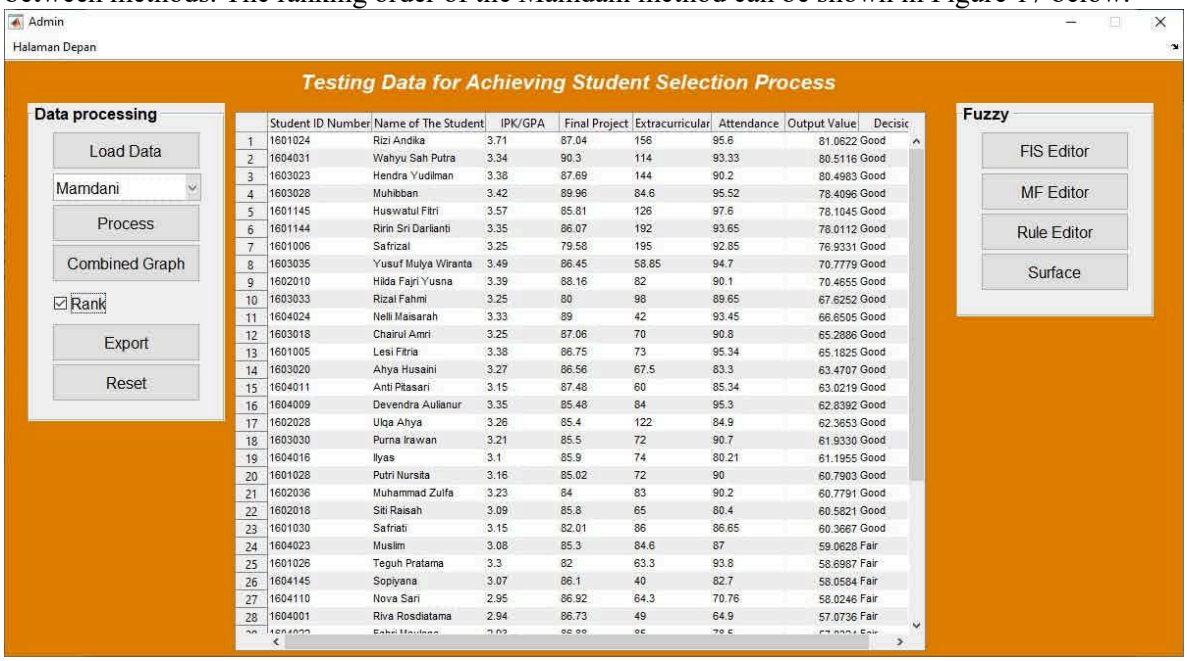


Figure 16. Graph of the Mamdani and Sugeno method student data testing

D. The rank of test output results

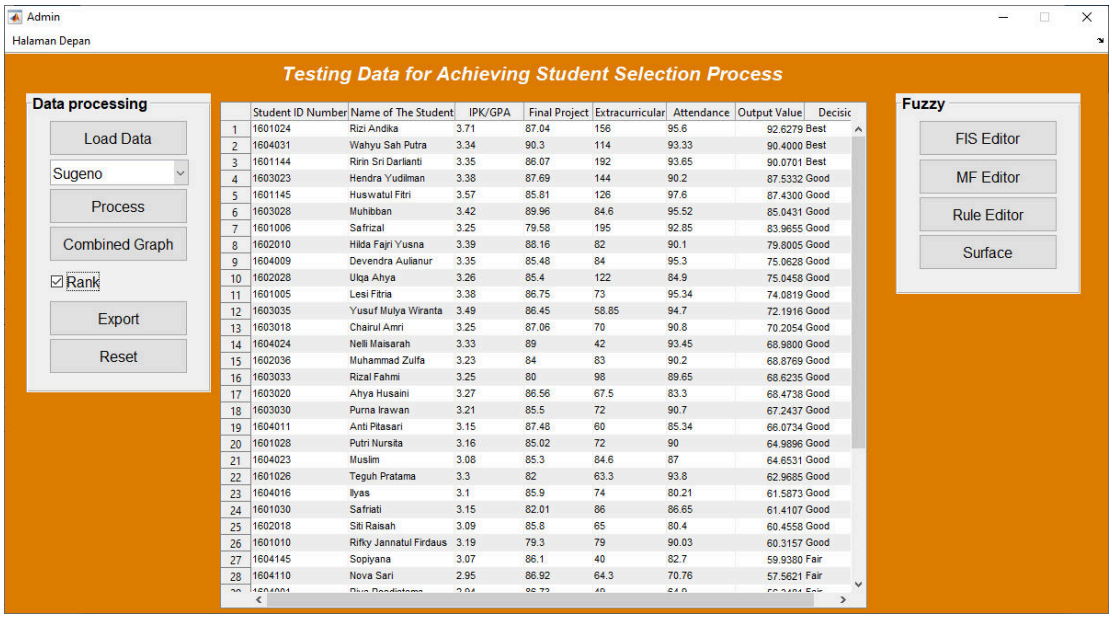
After all the data has been inputted, then sorting the data or ranking the data from the largest to the smallest output is carried out. The ranking results between the Mamdani and Sugeno methods have differences in order. This is because the system in the final decision has differences between methods. The ranking order of the Mamdani method can be shown in Figure 17 below.



	Student ID Number	Name of The Student	IPK/GPA	Final Project	Extracurricular	Attendance	Output Value	Decisic
1	1601024	Rizi Andika	3.71	87.04	156	95.6	81.0622	Good
2	1604031	Wahyu Sah Putra	3.34	90.3	114	93.33	80.5116	Good
3	1603023	Hendra Yudilman	3.38	87.69	144	90.2	80.4983	Good
4	1603028	Muhibban	3.42	89.96	84.6	95.52	78.4096	Good
5	1601145	Huswatul Fitri	3.57	85.81	126	97.6	78.1045	Good
6	1601144	Ririn Sri Darlianti	3.35	86.07	192	93.65	78.0112	Good
7	1601006	Safrizal	3.25	79.58	195	92.85	76.9331	Good
8	1603035	Yusuf Mulya Wiranta	3.49	86.45	58.85	94.7	70.7779	Good
9	1602010	Hilda Fajri Yusna	3.39	88.16	82	90.1	70.4655	Good
10	1603033	Rizal Fahmi	3.25	80	98	89.65	67.6252	Good
11	1604024	Nelli Maisarah	3.33	89	42	93.45	66.6505	Good
12	1603018	Chairul Amri	3.25	87.06	70	90.8	65.2886	Good
13	1601005	Lesi Fitria	3.38	86.75	73	95.34	65.1825	Good
14	1603020	Ahya Husaini	3.27	86.56	67.5	83.3	63.4707	Good
15	1604011	Anti Pitasari	3.15	87.48	60	85.34	63.0219	Good
16	1604009	Devendra Aulianur	3.35	85.48	84	95.3	62.8392	Good
17	1602028	Ulqa Ahya	3.26	85.4	122	84.9	62.3653	Good
18	1603030	Purna Irawan	3.21	85.5	72	90.7	61.9330	Good
19	1604016	Ilyas	3.1	85.9	74	80.21	61.1955	Good
20	1601028	Putri Nursita	3.16	85.02	72	90	60.7903	Good
21	1602036	Muhammad Zulfa	3.23	84	83	90.2	60.7791	Good
22	1602018	Siti Raisah	3.09	85.8	65	80.4	60.5821	Good
23	1601030	Safriati	3.15	82.01	86	86.65	60.3667	Good
24	1604023	Muslim	3.08	85.3	84.6	87	59.0628	Fair
25	1601026	Teguh Pratama	3.3	82	63.3	93.8	58.6987	Fair
26	1604145	Sopiyana	3.07	86.1	40	82.7	58.0584	Fair
27	1604110	Nova Sari	2.95	86.92	64.3	70.76	58.0246	Fair
28	1604001	Riva Rosdiatama	2.94	86.73	49	64.9	57.0736	Fair

Figure 17. Ranking results using the Mamdani method

After sorting the output value from the values is shifted to the lowest, then an Export process is carried out for data storage. The steps for ranking and exporting data can also be done using the Sugeno method. From the tests, it found that the students with the highest score with the Mandani method are students on behalf of Student 04 with an output value of 81.06 in the "Good" category. While using the Sugeno method, the name of the student who was declared students also obtained "Best" on the same name, namely Student 04, with an output value of 92.63. The test results using the Sugeno method can be seen in Figure 18 below.



	Student ID Number	Name of The Student	IPK/GPA	Final Project	Extracurricular	Attendance	Output Value	Decisic
1	1601024	Rizi Andika	3.71	87.04	156	95.6	92.6279	Best
2	1604031	Wahyu Sah Putra	3.34	90.3	114	93.33	90.4000	Best
3	1601144	Ririn Sri Darlianti	3.35	86.07	192	93.65	90.0701	Best
4	1603023	Hendra Yudilman	3.38	87.69	144	90.2	87.5332	Good
5	1601145	Huswatul Fitri	3.57	85.81	126	97.6	87.4300	Good
6	1603028	Muhibban	3.42	89.96	84.6	95.52	85.0431	Good
7	1601006	Safrizal	3.25	79.58	195	92.85	83.9655	Good
8	1602010	Hilda Fajri Yusna	3.39	88.16	82	90.1	79.8005	Good
9	1604009	Devendra Aulianur	3.35	85.48	84	95.3	75.0628	Good
10	1602028	Ulqa Ahya	3.26	85.4	122	84.9	75.0458	Good
11	1601005	Lesi Fitria	3.38	86.75	73	95.34	74.0819	Good
12	1603035	Yusuf Mulya Wiranta	3.49	86.45	58.85	94.7	72.1916	Good
13	1603018	Chairul Amri	3.25	87.06	70	90.8	70.2054	Good
14	1604024	Nelli Maisarah	3.33	89	42	93.45	68.9800	Good
15	1602036	Muhammad Zulfa	3.23	84	83	90.2	68.8769	Good
16	1603033	Rizal Fahmi	3.25	80	98	89.65	68.6235	Good
17	1603020	Ahya Husaini	3.27	86.56	67.5	83.3	68.4738	Good
18	1603030	Purna Irawan	3.21	85.5	72	90.7	67.2437	Good
19	1604011	Anti Pitasari	3.15	87.48	60	85.34	66.0734	Good
20	1601028	Putri Nursita	3.16	85.02	72	90	64.9896	Good
21	1604023	Muslim	3.08	85.3	84.6	87	64.6531	Good
22	1601026	Teguh Pratama	3.3	82	63.3	93.8	62.9685	Good
23	1604016	Ilyas	3.1	85.9	74	80.21	61.5873	Good
24	1601030	Safriati	3.15	82.01	86	86.65	61.4107	Good
25	1602018	Siti Raisah	3.09	85.8	65	80.4	60.4558	Good
26	1601010	Rifky Jannatul Firdaus	3.19	79.3	79	90.03	60.3157	Good
27	1604145	Sopiyana	3.07	86.1	40	82.7	59.9380	Fair
28	1604110	Nova Sari	2.95	86.92	64.3	70.76	57.5621	Fair

Figure 18. Ranking results using the Sugeno method

E. Analysis of the Mamdani and Sugeno fuzzy methods

The results of the comparison between testing with the Mamdani and Sugeno fuzzy logic methods obtained a distinct difference in numbers, both testing with the Mamdani method or Sugeno method, both of these methods have been tested which produce new data, so users can use which way to use in the data testing process. In determining outstanding students at the South Aceh Polytechnic. The following tables and graphs illustrate the comparison results obtained after testing. For more details, see the following Tables and Graphs.

Table 4. Comparison of Test Results

No	Name of the student	Testing Method					
		Mamdani			Sugeno		
		Output	Decision	Rank	Output	Decision	Rank.
1	Student01	65.18	Fair	13	74.08	Good	11
2	Student02	76.93	Good	7	83.97	Best	7
3	Student03	54.46	Fair	30	60.32	Fair	26
4	Student04	81.06	Best	1	92.63	Best	1
5	Student05	58.70	Fair	25	62.91	Fair	22
6	Student06	60.79	Fair	20	64.99	Fair	20
7	Student07	60.37	Fair	23	61.41	Fair	24
8	Student08	24.76	Poor	39	14.43	Poor	39
9	Student09	78.01	Good	6	90.07	Best	3
10	Student10	78.10	Good	5	87.43	Best	5
11	Student11	41.10	Poor	36	40.60	Poor	35
12	Student12	70.47	Good	9	79.80	Good	8
13	Student13	60.58	Fair	22	60.46	Fair	25
14	Student14	24.76	Poor	40	14.43	Poor	40
15	Student15	62.37	Fair	17	75.05	Good	10
16	Student16	45.18	Fair	34	44.03	Poor	34
17	Student17	60.78	Fair	21	68.88	Fair	15
18	Student18	35.82	Poor	38	32.55	Poor	38
19	Student19	37.97	Poor	37	34.67	Poor	37
20	Student20	42.97	Poor	35	39.42	Poor	36
21	Student21	46.52	Fair	33	47.28	Fair	33
22	Student22	53.73	Fair	31	51.49	Fair	31
23	Student23	65.29	Fair	12	70.21	Good	13
24	Student24	63.59	Fair	14	68.58	Fair	17

No	Name of the student	Testing Method					
		Mamdani			Sugeno		
		Output	Decision	Rank	Output	Decision	Rank.
Be	Student25	80.50	Best	3	87.53	Best	4
26	Student26	78.60	Good	4	85.27	Best	6
27	Student27	61.93	Fair	18	67.24	Fair	18
28	Student28	67.63	Fair	10	68.62	Fair	16
29	Student29	70.81	Good	8	72.24	Good	12
30	Student30	50.94	Fair	32	50.30	Fair	32
31	Student31	57.07	Fair	28	56.35	Fair	29
32	Student32	62.84	Fair	16	75.06	Good	9
33	Student33	63.02	Fair	15	66.07	Fair	19
34	Student34	61.20	Fair	19	61.59	Fair	23
35	Student35	57.03	Fair	29	56.08	Fair	30
36	Student36	59.27	Fair	24	64.75	Fair	21
37	Student37	66.65	Fair	11	68.98	Fair	14
38	Student38	80.51	Best	2	90.40	Best	2
39	Student39	58.02	Fair	27	57.56	Fair	28
40	Student40	58.06	Fair	26	59.94	Fair	27

From the test results, it can be seen that the comparison of the two methods used, the error rate process of these two methods, is obtained from the calculation of the average results of each input variable. This intermediate result is used as the initial test value before the testing process is carried out using the Mamdani and Sugeno fuzzy logic methods. Each input variable with the test results of the two ways in making student achievers decisions, the error rate amount can use equation (4).

$$MPE = \frac{\sum_{t=1}^{n} \frac{(Y_t - \hat{Y}_t)}{Y_t} x\ 100\%}{n} \quad (4)$$

Using the MPE formula, the truth value can be solved using the mean percent error value / also known as the Mean Percentage Error (MPE), as in Table 5 below:

Table 5. Calculation results of the Mean Percentage Error level

No	Name of the student	Initial value	Mamdani			Sugeno		
			Output	Error	MPE	Output	Error	MPE
1	Student01	64.62	65.18	0.59	0.91	74.08	9.46	12.78
2	Student02	92.67	76.93	15.74	16.98	83.97	8.70	10.36
3	Student03	62.88	54.46	8.42	13.39	60.32	2.56	4.24
4	Student04	85.59	81.06	4.53	5.29	92.63	7.04	7.60
5	Student05	60.60	58.70	1.90	3.14	62.91	2.31	3.66
6	Student06	62.55	60.79	1.75	2.81	64.99	2.44	3.76
7	Student07	64.45	60.37	4.09	6.34	61.41	3.04	4.95
8	Student08	52.43	24.76	27.67	52.78	14.43	38.00	263.41
9	Student09	93.77	78.01	15.76	16.80	90.07	3.70	4.11
10	Student10	78.25	78.10	0.14	0.18	87.43	9.19	10.51
11	Student11	57.37	41.10	16.26	28.35	40.60	16.77	41.31
12	Student12	65.91	70.47	4.55	6.90	79.80	13.89	17.40
13	Student13	58.57	60.58	2.01	3.43	60.46	1.88	3.12
14	Student14	54.38	24.76	29.62	54.47	14.43	39.95	276.93
15	Student15	73.89	62.37	11.52	15.60	75.05	1.16	1.54
16	Student16	55.62	45.18	10.43	18.76	44.03	11.58	26.30
17	Student17	65.11	60.78	4.33	6.65	68.88	3.77	5.47
18	Student18	55.72	35.82	19.89	35.70	32.55	23.16	71.15
19	Student19	54.62	37.97	16.65	30.49	34.67	19.95	57.54
20	Student20	62.48	42.97	19.51	31.23	39.42	23.06	58.50
21	Student21	63.93	46.52	17.41	27.24	47.28	16.65	35.22
22	Student22	53.54	53.73	0.19	0.35	51.49	2.05	3.98

No	Name of the student	Initial value	Mamdani			Sugeno		
			Output	Error	MPE	Output	Error	MPE
23	Student23	62.78	65.29	2.51	4.00	70.21	7.43	10.58
24	Student24	60.16	63.59	3.43	5.70	68.58	8.42	12.28
25	Student25	81.32	80.50	0.82	1.01	87.53	6.22	7.10
26	Student26	68.38	78.60	10.23	14.96	85.27	16.90	19.81
27	Student27	62.85	61.93	0.92	1.46	67.24	4.39	6.53
28	Student28	67.73	67.63	0.10	0.15	68.62	0.90	1.31
29	Student29	60.87	70.81	9.94	16.33	72.24	11.36	15.73
30	Student30	67.24	50.94	16.29	24.23	50.30	16.93	33.66
31	Student31	50.89	57.07	6.18	12.14	56.35	5.46	9.68
32	Student32	67.03	62.84	4.19	6.26	75.06	8.03	10.70
33	Student33	58.99	63.02	4.03	6.83	66.07	7.08	10.72
34	Student34	60.80	61.20	0.39	0.64	61.59	0.78	1.27
35	Student35	63.33	57.03	6.30	9.94	56.08	7.25	12.93
36	Student36	65.00	59.27	5.73	8.81	64.75	0.24	0.37
37	Student37	56.95	66.65	9.71	17.05	68.98	12.04	17.45
38	Student38	75.24	80.51	5.27	7.00	90.40	15.16	16.77
39	Student39	56.23	58.02	1.79	3.18	57.56	1.33	2.31
40	Student40	52.97	58.06	5.09	9.61	59.94	6.97	11.63
Total Error percentage				527.09			1124.66	
Average Percentage of errors				13.18			28.12	
Data correctness level				86.82 %			71.88 %	

From Table 5 above, from the calculations that have been done using the formula to find the actual value by calculating the mean percent error value or also known as the Mean Percentage Error (MPE), the average percentage error rate results from calculations using both methods. The fuzzy Mamdani logic testing method obtained a total of 527.09 divided by the amount of data, namely 40 parts. The results of this division obtained an average error rate of 13.18%. While the truth level from these calculations' effects is 100% minus 13.18%, then the truth level is 86.82%. While the Sugeno fuzzy logic test method obtained a total of 1124.66 divided by the amount of data, namely 40 parts, this division's results got an average error rate of 28.12%. while the level of truth from the effects of these calculations is 100% minus 28.12%, then the truth level is 71.88%

V. Conclusion

Based on the results of research on the study of the implementation of the decision-making process for the selection of outstanding students at the South Aceh Polytechnic using the Mamdani and Sugeno fuzzy logic method, it can be concluded that:

1. The stages in selecting outstanding students begin with determining the fuzzy set, determining the application of the implication function, compiling the rules used in the fuzzification calculation process, determining defuzzification to get a firm value of the decision results, ranking methods, and selecting a list of names that are included in the highest score as outstanding students.
2. The testing process can be presented in a Graphic User Interface (GUI) display in Matlab 2015a so that the user or admin can input data into the system that has been built for the output process.
3. A comparison of the correct level value in the study, with 40 students obtained a different level of truth. For the Fuzzy Mamdani logic method, the right level is 86.82%, while the application of Fuzzy Sugeno logic gets a truth level of 71.88%.

References

[1] Muna Erawati, “Prestasi Akademik Siswa Dalam Kaitannya Dengan Motivasi Akademik, Persepsi Terhadap Dukungan Akademik Dan Peran Orang Tua,” Universitas Gajah Mada, 2015.

[2] R. A. Purba, “Memprediksi Prestasi Mahasiswa Politeknik Unggul LP3M dengan Menggunakan

Jaringan Saraf Tiruan dan Fuzzy," *Semin. Nas. Teknol. Inf. dan Multimed.*, pp. 1–6, 2018.

[3] M. Irfan, L. P. Ayuningtias, and J. Jumadi, "Analisa Perbandingan Logic Fuzzy Metode Tsukamoto, Sugeno, Dan Mamdani (Studi Kasus : Prediksi Jumlah Pendaftar Mahasiswa Baru)," *J. Tek. Inform.*, vol. 10, no. 1, pp. 9–16, 2018, doi: 10.15408/jti.v10i1.6810.

[4] D. L. Rahakbauw, "Penerapan Logika Fuzzy Metode Sugeno Berdasarkan Data Persediaan Dan Jumlah Permintaan (Studi Kasus : Pabrik Roti Sarinda Ambon) Application of Fuzzy Logic Method Sugeno To Determine the Total Production of Bread ," vol. 9, pp. 121–134, 2015.

[5] E. Mahargia, D. Anggraeni P, R. Wandiro S, and Y. Mahzar, "Penerapan Logika Fuzzy Metode Sugeno untuk Sistem Pendukung Keputusan Prakiraan Cuaca," Universitas Brawijaya, 2013.

[6] A. Wantoro and A. T. Priandika, "Komparasi Perhitungan Pemilihan Mahasiswa Terbaik Menggunakan Metode Statistik Klasik Dengan Logika Fuzzy (Tsukamoto Dan Mamdani," *Semin. Nas. Teknol. Inf.*, pp. 25–32, 2017.

[7] V. D. Kouloumpis, V. S. Kouikoglou, and Y. A. Phillis, "Sustainability Assessment of Nations and Related Decision Making Using Fuzzy Logic," *IEEE Syst. J.*, vol. 2, no. 2, pp. 224–236, 2008, DOI: 10.1109/JSYST.2008.925256.

[8] Sri Kusumadewi, *Aplikasi Logika Fuzzy untuk Pendukung Keputusan2*. Yogyakarta: Graha Ilmu, 2013.

[9] Ferdinandus and I. luvi I. Astutik, "Sistem pendukung keputusan untuk membantu siswa sma kelas xii dalam menentukan jurusan di perguruan tinggi dengan menggunakan logika fuzzy metode mamdani," *Sist. Nas. "Inovasi dalam Desain dan Teknol.*, pp. 158–168, 2015.

[10] M. Stetnicha, B. De Baets, and L. Noskova, "Arithmetic fuzzy models," *IEEE Trans. Fuzzy Syst.*, vol. 18, no. 6, pp. 1058–1069, 2010, DOI: 10.1109/TFUZZ.2010.2062522.

[11] Amsar, R. Munadi, and R. Adriman, "Seleksi Beasiswa Untuk Perguruan Tinggi Berdasarkan Pendekatan Keputusan Berkeadilan Dengan Fuzzy Mamdani," *J. Inotera*, vol. 2, no. 2, pp. 1–8, 2017.

[12] Fajar Solikin, "Aplikasi Logika Fuzzy dalam Optimisasi Produksi Barang Menggunakan Metode Mamdani dan Metode Sugeno," Yogyakarta, 2011.

[13] M. D. Irawan, "Sistem Pendukung Keputusan Menentukan Matakuliah Pilihan pada Kurikulum Berbasis KKNI Menggunakan Metode Fuzzy Sugeno," vol. 13, no. 1, pp. 27–35, 2017.

[14] Kusrini, *Pengenalan Sistem Informasi*. Yogyakarta: Andi, 2007.

[15] H. Iqbal, *Pokok-pokok Materi Statistika 2 (Statistik Inferensif)*, 2nd ed. Jakarta: PT.Bumi Aksara, 2010.

[16] S. Nurhayati and I. Immanudin, "Penerapan Logika Fuzzy Mamdani untuk Prediksi Pengadaan Peralatan Rumah Tangga Rumah Sakit Application of Fuzzy Mamdani Logic for Procurement Predictions Hospital Household Appliances," vol. 8, no. 28, pp. 81–87, 2019, doi: 10.34010/komputika.v8i2.2254.