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RESEARCH ARTICLE

Graphical user interface-based fuzzy logic system for efficient student selection in Sekolah Berasrama Penuh, Malaysia

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Abstract - The selection process for Malaysia's Sekolah Berasrama Penuh (SBP) is essential for identifying and providing opportunities to qualified students who demonstrate strong academic performance, leadership skills, and active participation in cocurricular activities. Nonetheless, various inefficiencies, including potential biases, inconsistent judgments from evaluators, and prolonged procedures, hinder the current manual evaluation system. This study investigates these limitations through a qualitative methodology that includes in-depth interviews with SBP evaluators and a thorough examination of current selection criteria and procedures. The findings highlight multiple critical challenges associated with the manual system, including the labour-intensive process of handling multiple evaluation criteria, the inherent subjectivity in assessments, and variability in interpretations among evaluators. This project seeks to create a system grounded in fuzzy logic to transform the selection process for SBP. The fuzzy logic model was developed in MATLAB, using academic, leadership, and co-curricular scores as input variables. The analysis yielded a thorough, proportionate assessment for each candidate. A Mamdani FIS is used to build a model that addresses subjectivity in non-academic assessments, thereby enhancing equity and consistency among candidates. A user-friendly graphical user interface (GUI) has been developed using MATLAB as a desktop application, facilitating easy data input and enabling quick evaluations. The findings indicate that adopting an automated system powered by fuzzy logic may greatly enhance both the fairness and efficiency of student selection for SBP Malaysia.

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1. Introduction

The Sekolah Berasrama Penuh (SBP) in Malaysia is a distinctive component of the nation's educational system. It is renowned for its commitment to holistic development, academic performance, and the cultivation of the potential of exceptional students nationwide. To enable students to compete on a global scale by highlighting mastery of 21st-century abilities such as critical thinking, creativity and invention, problem-solving, and leadership, it has been widely studied on the website of the Kementerian Pendidikan Malaysia [1]. SBP was established to provide a supportive learning environment and plays a crucial role in nurturing future leaders and innovators in Malaysia. However, Mulyadi's [2] process for selecting new students is an integral part of the admissions procedures. The process of selecting students within institutions significantly impacts both individuals and the broader educational landscape. The conventional method of selecting students for admission to SBP schools in Malaysia aims to identify candidates who possess the intelligence and academic drive necessary for success in their studies. Determining qualified applicants from a large pool presents significant challenges. The approach is thought to require a significant investment in time. This manual method is often viewed as less effective and efficient, as an increase in the number of components or data utilized can complicate issues further. To overcome this challenge and improve the student selection process for SBP schools in Malaysia, a weighted-factor system is necessary.

Lotfi A. Zadeh's 1965 publication "Fuzzy Sets" in Rojas et al. [3] is considered a seminal work that established the principles of fuzzy logic. Researchers have employed fuzzy logic to assess procedures for tests or activities, facilitating a linguistic analysis of the outcomes. The fuzzy logic system was employed to enhance the exam grading process, considering the complexity of each question and the estimated time required for responses. Zadeh's article established the foundation of fuzzy logic theory by introducing fuzzy sets and demonstrating their application in modelling and reasoning with imprecise data. Fuzzy logic is a framework comprising a set of concepts, principles, and methods for approximate reasoning that relies on linguistic connections between degrees of membership in fuzzy sets and the degrees of truth of related fuzzy propositions [4]. It diminishes uncertainty, ambiguity, vagueness, and imprecision as illustrated above. It will also consider factors such as students' academic performance, engagement in co-curricular activities, and leadership abilities. The application of fuzzy logic in the student selection process enables the integration of both subjective and objective weights for each candidate parameter, thereby facilitating a more rational and comprehensive evaluation.

The selection system, utilizing fuzzy logic, is integrated with a graphical user interface in MATLAB to improve accessibility and usability. Aziz et al. [5] state that a graphical user interface is a program designed to enhance user-friendliness through visual elements. The graphical user interface provides an engaging platform for inputting student

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information, encompassing academic achievements, leadership skills, and extracurricular involvement. The ultimate selection score is derived by applying fuzzy logic to the inputs. Ultimately, this would ensure that the selection process for students entering SBP schools in Malaysia is more effective and efficient, admitting only those who are truly worthy and deserving.

2. Methodology

Fuzzy logic is a method of variable processing that allows multiple possible truth values to be handled by a single variable. The main objective is to create a control system that ensures the system's transient and steady-state response. A fuzzy logic system is designed to evaluate all the input data and produce a solution, as studied in Adil et al. [6]. Lotfi Zadeh developed a fuzzy logic system in 1965, essentially a development of the traditional binary logic system. The system considers the idea of partial truth, with truth values ranging from 0 to 1. This method allows for more thorough decision-making in situations while recognizing the individuality and the subjectivity of the situation. Nowadays, fuzzy logic is widely recognized as a useful method for decision-making in complex, unpredictable contexts. According to Adil et al. [6], a membership function, denoted A(x), is a curve that assigns each point in the input space a membership value, or degree of membership, ranging from 0 to 1. This number represents the level of membership of element x in a specific fuzzy collection. The types of membership functions most frequently used in literature are the Gaussian Membership Function, S-curve Membership Function, Triangular Membership Function, and Trapezoidal Membership Function. A trapezoidal membership function is defined by its lower and upper bounds (a and d, respectively), as well as the lower and upper limits of its nucleus (b and c).

$$\mu_A(x)\begin{cases} 1 & \text{for } b \leq x \leq c \\ \dfrac{x-a}{b-a} & \text{for } a \leq x \leq b \\ \dfrac{d-x}{d-c} & \text{for } c \leq x \leq d \\ 0 & \text{for } x \leq a \text{ or } x \geq d \end{cases} \tag{1}$$

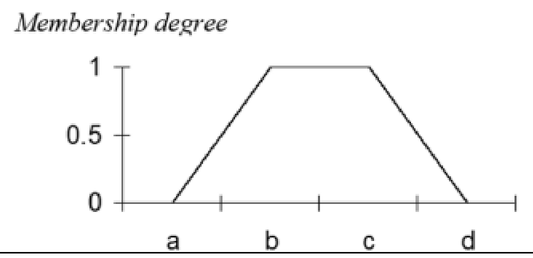

Figure 1. Basic trapezoidal figure

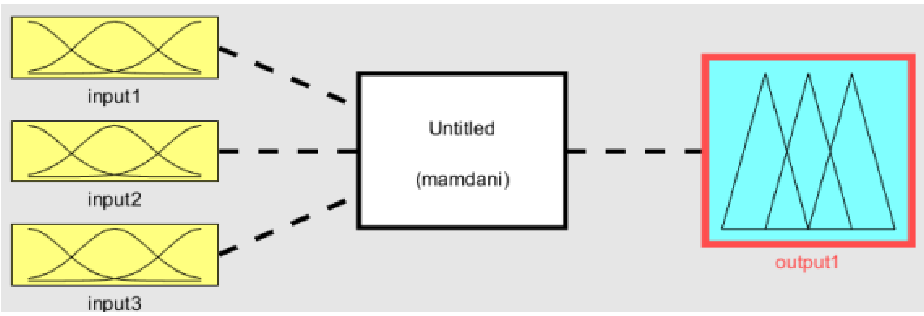

Figure 2. Mamdani fuzzy inference system

Zadeh proposed a Mamdani fuzzy inference system. It is a nonlinear mapping methodology in which an output element is derived from the input data using fuzzy logic. The mapping relies on fuzzy logic. It is a tool for constructing systems that use specific current knowledge and expertise as information in Agarwal et al. [7]. Mamdani fuzzy inference was originally proposed as a means of generating a control system by synthesizing a set of linguistic control rules from experienced human operators. The advantages attached to the Mamdani model are several. The model is easy to learn, understand, and implement. It is also very well suited to incorporating human input in a natural, friendly way. It also has a readily interpretable rule basis, improving transparency and understandability. It is due to these properties that this technique is widely accepted and used across a wide array of applications. A basic trapezoidal figure is given in Figure 1, and a Mamdani fuzzy inference system is given in Figure 2.

In classical logic, the IF-THEN operation is expressed as IF p THEN q, represented by p → q. Here, the symbol "→" functions as a logical connective, signifying the implication relationship between the propositions p (antecedent) and q (consequent). A fuzzy IF-THEN rule is a conditional statement expressed as

IF <FP1> THEN <FP2> (2)

where FP is equal to a fuzzy proposition. In this study, a Mamdani model is preferred. According to Modus Ponens, the output of Mamdani is as follows:

$$\mu_{QMM}(x, y) = \min [\mu_{FP1}(x), \mu_{FP2}(y)] \quad (3)$$

The combined output of these fuzzy sets determines the fuzzy inference's overall output. This process entails merging the individual fuzzy sets and using fuzzy intersection operations to synthesize a cohesive result. The following equation shows how these operations are performed to integrate the fuzzy sets, ultimately defining the fuzzy inference system's final output.

$$\mu_{QMP}(x, y) = \mu_{FP1}(x) * \mu_{FP2}(y) \quad (4)$$

The purpose of the fuzzification mechanism is to transform clear external input data into relevant, semantically fuzzy information by using the attribution function as the mapping medium, as mentioned in the literature [8-9]. This is done through the medium of mapping with the aid of the attribution function. Therefore, choosing the right fuzzifier is very important to enable simpler calculations in the fuzzy inference engine. The input and linguistic values for the membership function are given in Table 1. The correct conversion of crisp inputs to appropriate fuzzy sets by a fuzzifier enhances the accuracy and efficiency of fuzzy reasoning. Therefore, this meticulous selection makes the operation of the fuzzy inference engine smoother and more effective, reduces computational complexity, and ultimately yields outputs that are more accurate and reliable.

Table 1. Input and linguistic value for membership function

Input	Linguistic Value	Range
Academic Performance (AP)	{Low, Medium, High}	[0, 50]
Co-curricular (C)	{Low, Medium, High}	[0, 30]
Leadership (L)	{Low, Medium, High}	[0, 20]

The fuzzy inference system derives its fuzzy output value from analysis and approximate or fuzzy inference based on the fuzzy system's rule base, according to Muchtar et al. [9]. Generally, a Fuzzy Inference System (FIS) comprises three components: a rule base, a database, and a reasoning mechanism. Consequently, the IF-THEN rules are utilized in processing these fuzzy sets in a sequence under the rule base of the system. The IF part of each rule, which is an antecedent, is evaluated for its level of satisfaction; the outputs are then combined into a single fuzzy set that is again defuzzified into a crisp output value. This method equips the system to handle uncertainty and perform approximate reasoning, making it well-suited for difficult decision-making tasks. Basically, the main functional blocks, which build the fuzzy controller, can be identified as the fuzzifier, fuzzy rule base, fuzzy inference engine, and defuzzifier, whose individual functions are as follows:

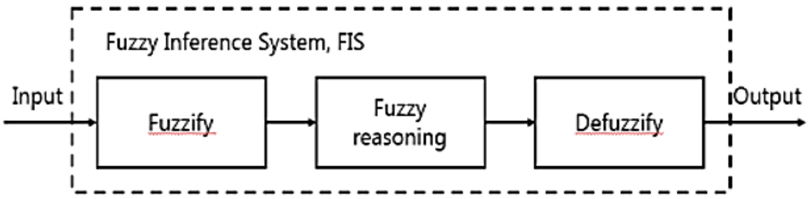

Figure 3. Process of individual-based inference

The process of extracting a single number from the combined fuzzy set's output is known as defuzzification, as shown in Figure 3. This is the last step in Fuzzy Logic Control. Its purpose is to convert the fuzzy inference results into a clear output, as described by Ahmed et al. [8]. Stated otherwise, a decision-making algorithm that chooses the optimal crisp value from a fuzzy set accomplishes defuzzification. MATLAB is used to create a graphical user interface for the multivariable frequency-sampling filter model. GUI can be easily understood as the interface between the user and the computer program, as stated in Aziz et al. [5]. They also stated that, usually based on the input users supply, users could find it difficult to understand the intended output. A graphical user interface is used to solve this problem. Effective communication between the user and the computer is made possible by the GUI, which acts as a bridge. GUIs enable users to interact with the system in a simple, intuitive manner through visual components such as input fields, buttons, and displays. In addition to increasing accessibility and ensuring that users can enter data effectively and view the results, this interface is designed to make complex processes easier to understand and navigate. By creating a visual overlay for the system, the GUI provides a more user-friendly experience and improves usability.

A few criteria have been taken into consideration in selecting students for SBP Malaysia, including academic performance, co-curricular activities, and leadership. Based on Aashish et al. [10], the term "academic" refers to any sort of formal education, including school education and college education for higher study. The author also states that in academia, "performance" refers to completing assigned responsibilities in accordance with an academic institution's predetermined standards to obtain an academic certificate, and it is often measured and evaluated by the grades or marks students achieve during the evaluation. Furthermore, "non-academic performance" refers to students' abilities that are not strictly academic, such as communication skills, attitude, general awareness, and engagement in extracurricular activities. In this study, in addition to exam scores, students' PBD, known as 'Pentaksiran Bilik Darjah,' is also included in the evaluation. Thus, to create a comprehensive evaluation, the best student is selected based on both categories, "academic performance" and "non-academic performance," to assess how well a student meets the specified requirements of institutional norms or the government education department. Therefore, performance measurement has been taken as the main characteristic in the student selection process, as it is the process of quantifying the efficiency and effectiveness of actions, which can be related to quality, time, cost, and flexibility, and has been widely studied in the literature [1].

Interest in student leadership, or leadership by young people, has long existed in school and community contexts, and numerous programs are dedicated to leadership development and training. According to Bautista and Espina [11], a common good leader is self-disciplined and aware of changes. They have a strong vision for the community and are productive and committed. They can engage, encourage, organize, and empower people to participate in collaborative actions to achieve common goals while sharing the decision-making process, according to Priya and Chandramathi [12]. As one of the objectives of the SBP Malaysia program is to develop long-standing student leadership, this criterion has been counted as one of the main selection factors for students. According to Shaikh et al. [13], co-curricular activities are activities that enhance and develop the fundamental curriculum. Students benefit from co-curricular activities because they give them the chance to put their knowledge and skills to use, explore new interests and abilities, and improve their social and organizational skills. Students who participate in extracurricular activities can gain practical experience that can benefit their academic performance. Based on a study by Bautista and Espina [11], active participation in co-curricular activities directly affected students' academic performance. According to Manuel et al. [14], co-curricular activities at school contribute to students' overall personality development, with the emphasis that students who actively participate in these activities have higher exam scores and are more motivated to learn. Therefore, co-curricular activities are believed to offer a more thorough evaluation of a student's ability, and they are included in the student selection process. The selection process can effectively identify well-rounded applicants who are likely to succeed in both academic and non-academic areas by evaluating these activities alongside academic achievements using fuzzy logic.

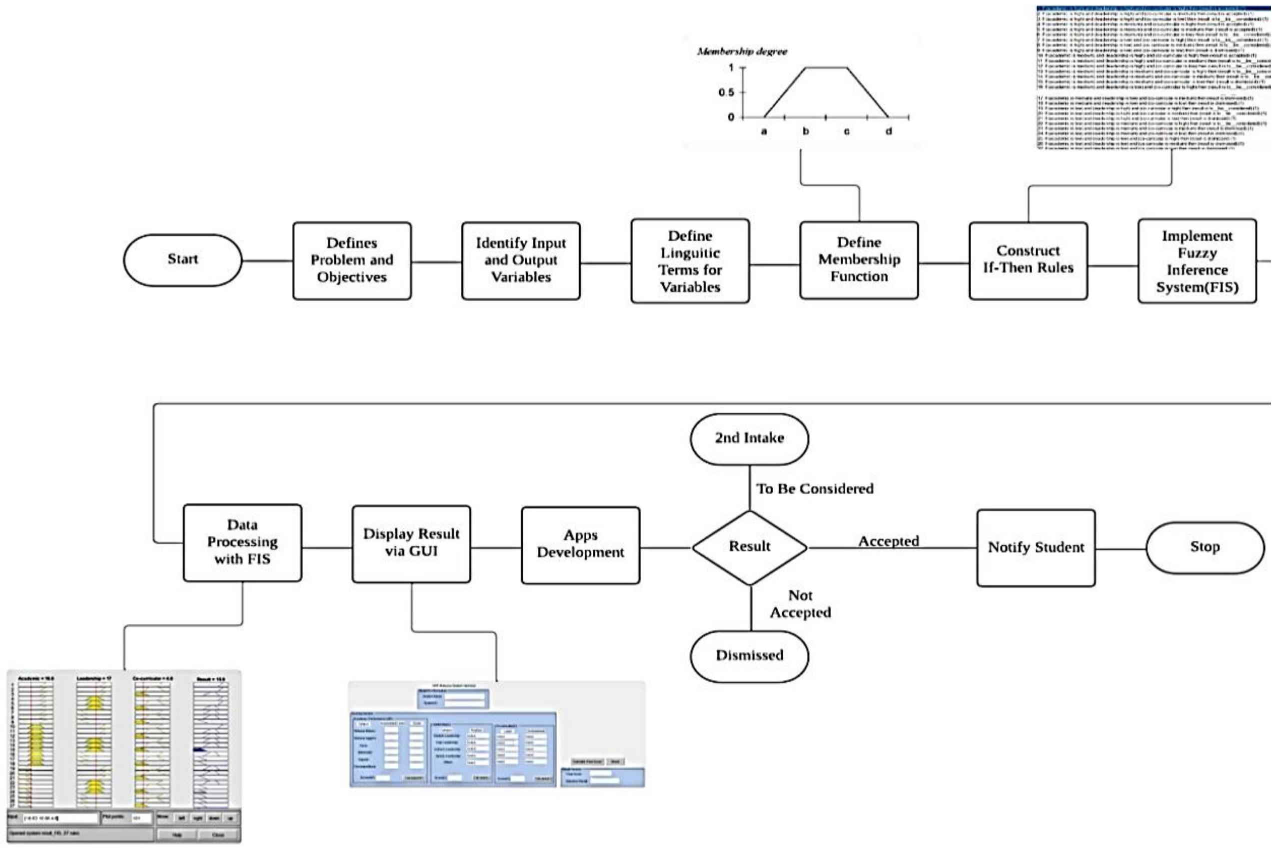

Figure 4. The implementation of the whole process

3. Results and Discussion

Figure 4 describes the overall structure of the work and the specific approach used to quantify and select students for SBP Malaysia using fuzzy logic. This chapter begins by outlining why and how a mixed-methods research design was chosen to study the highly complex selection process. This section covers how participants were sampled, the inclusion and exclusion criteria used, and the population sample size chosen to ensure that the study sample is nationally representative.

This research begins by outlining why and how a mixed-methods research design was chosen to study the highly complex selection process. This section covers how participants were sampled, the inclusion and exclusion criteria used, and the population sample size chosen to ensure that the study sample is nationally representative. Linguistic Variable, Linguistic Value, and Fuzzy Numbers are presented in Table 2. According to a study by Mulyadi et al. [2], the results of the Accuracy Test we performed indicate that all data are valid, as shown in Table 3. This is because of the results of the Fuzzy Mamdani Calculation Method, which we performed both manually and systematically, match.

Table 2. The linguistic variables, linguistic value, and fuzzy numbers

Variable	Fuzzy Sets	Symbol	Fuzzy Number	Range
Academic Performance (AP)	High	AP_1	[0, 0, 10, 20]	[0, 50]
	Medium	AP_2	[13, 21, 30, 37]	
	Low	AP_3	[30, 40, 50, 50]	
Leadership (L)	High	L_1	[0, 0, 3, 10]	[0, 30]
	Medium	L_2	[7, 13, 18, 24]	
	Low	L_3	[20, 25, 30, 30]	
Co-Curricular (C)	High	C_1	[0, 0, 3, 8]	[0, 20]
	Medium	C_2	[5, 8, 13, 17]	
	Low	C_3	[12, 16, 20, 20]	
Results (R)	Accepted	R_A	[0. 0, 15, 40]	[0, 100]
	To Be Considered	R_C	[27, 49, 62, 75]	
	Dismissed	R_C	[70, 85, 100, 100]	

List of membership functions for Results:

$$\mu_{Accepted}(x)\begin{cases} 1 & \text{for } 85 \le x \le 100 \\ \dfrac{x-70}{15} & \text{for } 70 \le x \le 85 \\ 0 & \text{for } x \le 70 \text{ or } x \ge 100 \end{cases} \tag{5}$$

$$\mu_{Considered}(x)\begin{cases} 1 & \text{for } 49 \le x \le 62 \\ \dfrac{x-27}{22} & \text{for } 27 \le x \le 49 \\ \dfrac{75-x}{13} & \text{for } 62 \le x \le 75 \\ 0 & \text{for } x \le 27 \text{ or } x \ge 75 \end{cases} \tag{6}$$

$$\mu_{Dismissed}(x)\begin{cases} 1 & \text{for } 0 \le x \le 15 \\ \dfrac{40-x}{25} & \text{for } 15 \le x \le 40 \\ 0 & \text{for } x \le 0 \text{ or } x \ge 40 \end{cases} \tag{7}$$

Table 3. Accuracy test between the manual (centroid calculation) result and the system result

Student	Criteria	Score	Result		Status		Validation
			Manual	System	Manual	System	
A	Academic Performance	40.64	88.3	88.4	Accepted	Accepted	Valid
	Leadership	18.26					
	Co-Curricular activities	8.20					
B	Academic performance	31.37	52.2	51.4	To be Considered	To be Considered	Valid
	Leadership	9.13					
	Co-Curricular Activities	15.20					
C	Academic Performance	18.63	14.8	15.8	Dismissed	Dismissed	Valid
	Leadership	19.96					
	Co-Curricular Activities	4.60					

In this study, the process that is used to identify the best student for the SBP program is called reasoning. The reasoning process follows the 27 rules created in the previous process. These criteria involve a few factors, including academic performance, leadership abilities, and co-curricular activities, which are weighed according to their importance in identifying the best candidates. Every candidature is systematically assessed against these guidelines by the reasoning process, which then assigns scores and decides whether to accept, consider, or reject the candidates. Figure 5 illustrates the system's outcome following evaluation against 27 established rules. With academic performance weighted at 40.6, leadership at 18.3, and co-curricular activities at 8.2, the cumulative score for an applicant totals 88.5. Consequently, based on this score, the system categorizes the student's result as "Accepted."

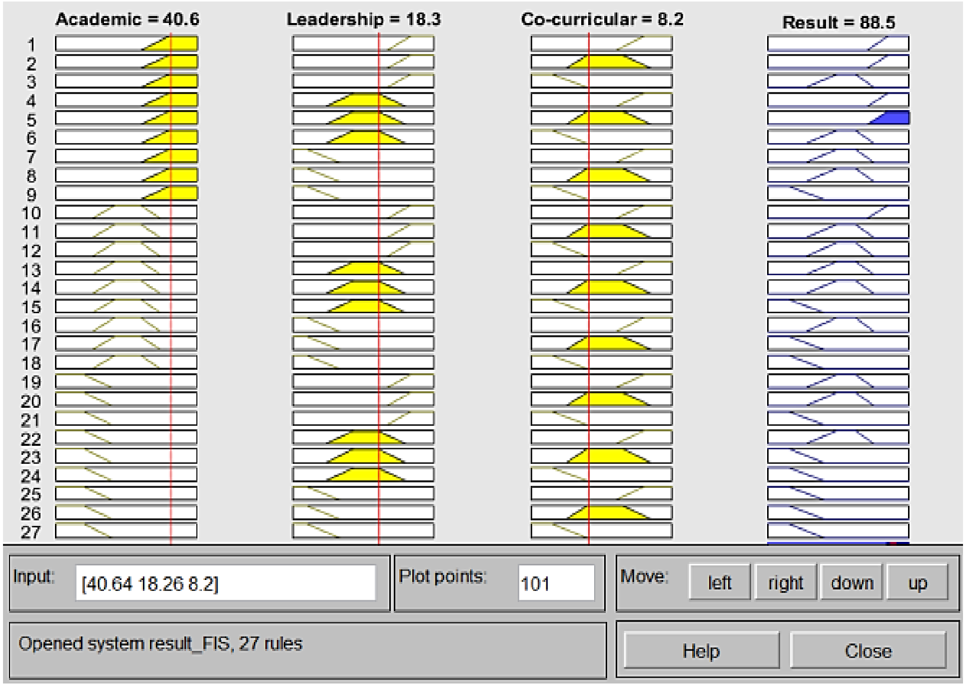

Figure 5. Graphical Rule Viewer for Result "Accepted" in a fuzzy logic toolbox

Figure 6 illustrates the system's outcome following evaluation against 27 established rules. With academic performance weighted at 31.4, leadership at 9.13, and co-curricular activities at 15.2, the cumulative score for an applicant totals 51.4. Consequently, based on this score, the system categorizes the student's result as "To Be Considered."

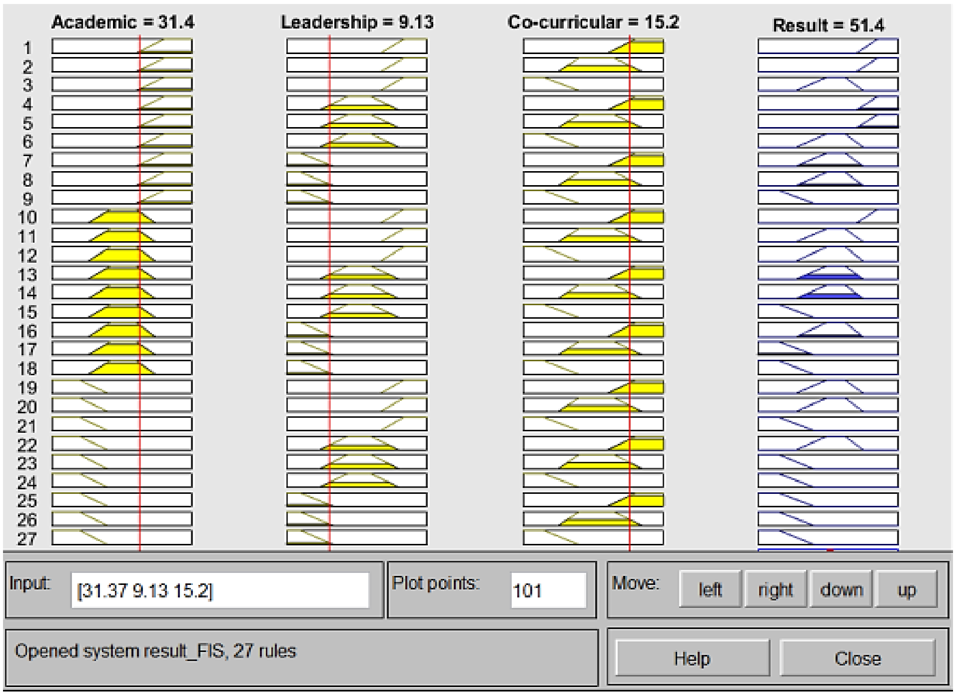

Figure 6. Graphical rule viewer for result "To Be Considered" in a fuzzy logic toolbox

Figure 7 illustrates the system's outcome following evaluation against 27 established rules. With academic performance weighted at 18.6, leadership at 17, and co-curricular activities at 4.6, the cumulative score for an applicant totals 15.9. Consequently, based on this score, the system categorizes the student's result as "Dismissed". Based on the diagram, the SBP Malaysia Student Optimiser determines the students' co-curricular activities, leadership, and academic performance. A score of 40.64 is obtained by processing the results for six subjects in academic performance. Positions such as class monitor and emcee contribute to a leadership score of 18.26. Co-curricular accomplishments, such as placing second at the state level, contribute to the 8.20 score. All these scores are combined into a final score of 88.4728, and the algorithm uses fuzzy logic to assign the student's name, Aishah, and the selection result is Accepted. The result obtained was equivalent to that shown in the Graphical Rule Viewer in Figure 8.

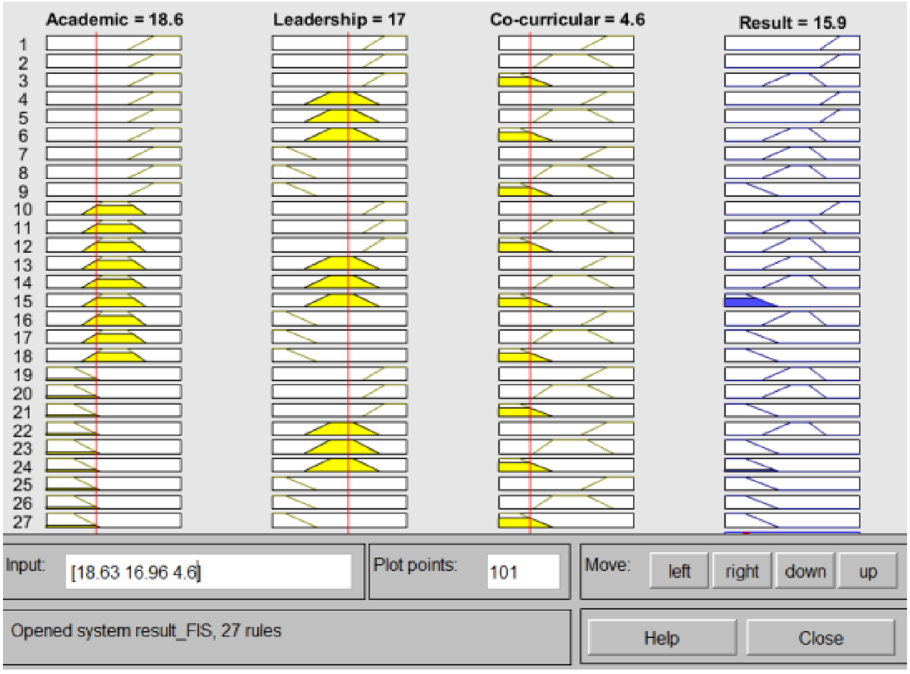

Figure 7. Graphical rule viewer for result "Dismissed" in a fuzzy logic toolbox

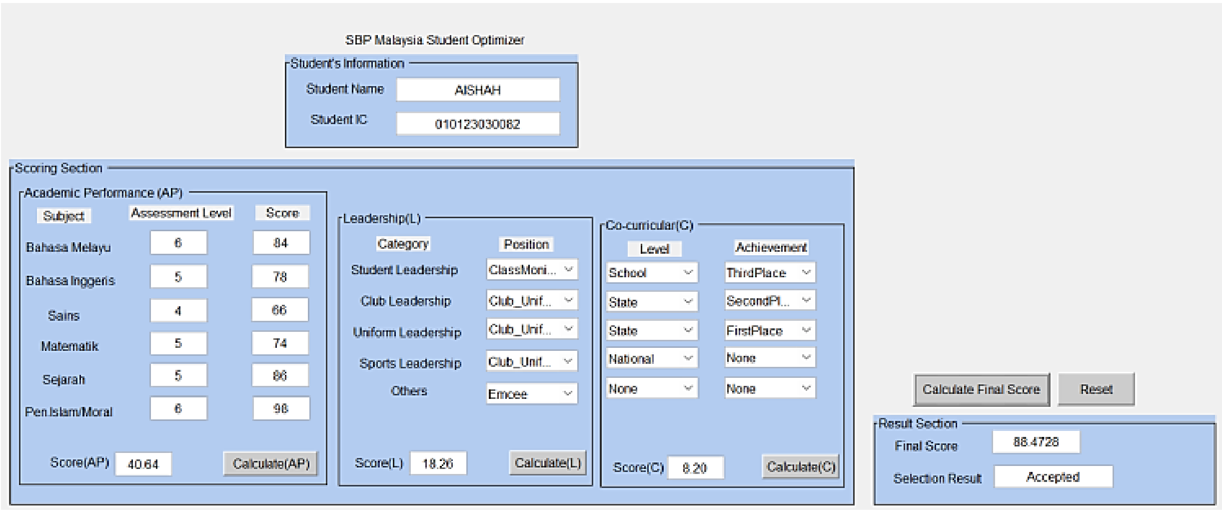

Figure 8. Graphical user interface for result "Accepted"

Table 4. Result of three students for SBP selection using the Fuzzy Logic toolbox and GUI

Criteria	Student A	Student B	Student C
Academic Performance	40.64	31.37	18.63
Leadership	18.26	9.13	16.96
Co-Curricular Activities	8.20	15.20	4.60
Final Score	88.47	51.43	15.88
Selection Result	Accepted	To be considered	Dismissed

The scores shown in Table 4 are the overall performance of three students, Student A, Student B, and Student C, in the SBP selection process utilizing the Fuzzy Logic Toolbox and GUI. The review was conducted based on three key criteria: academic performance, leadership, and co-curricular activities. With scores of 40.64, 31.37, and 18.63, respectively. Student A had the highest academic achievement among the students. In terms of leadership, Student A continues to hold the top spot with 18.26, followed by Student C with 16.96 and Student B with 9.13. In terms of extracurricular activities, Student B has the highest score (15.20), followed by Student A (8.20) and Student C (4.60). The final score was obtained by applying the Fuzzy Logic Toolbox and GUI to combine the three criteria. With the highest final score of 88.47, Student A gets "Accepted." With a score of 51.43, Student B falls into the "To Be Considered" category, meaning more evaluation may be necessary before a final judgement is made. Due to extremely poor performance on the criterion evaluated in this case, Student C received the lowest rating of 15.88, placing him in the "Dismissed" category. Table 4 also demonstrates how effective the Fuzzy Logic Toolbox and GUI are at conducting thorough, organized assessments, enabling judgments to be made based on a fair assessment of students' academic performance, leadership abilities, and co-curricular activities.

4. Conclusions

In conclusion, the implementation of the GUI-based fuzzy logic system for student selection in SBP Malaysia has successfully addressed the inefficiency and subjectivity of the traditional manual process. It uses fuzzy logic to analyze a few inputs, such as students' academic performance, leadership, and co-curricular activities. While making their selections, ensure that the process is fair and transparent. A fuzzy inference system implemented in MATLAB will consider multiple criteria effectively while minimizing biases and inconsistencies common to human judgment. This makes the system highly practical, especially since a user-friendly GUI lets users simply enter data and receive instant evaluation results. The program effectively produced ranked outputs, allowing decision makers to quickly find the best applicants, where Student A, Student B, and Student C obtained "Accepted," "To Be Considered," and "Dismissed" as their results, respectively. Thus, the invention can be seen as improving selection efficiency while also providing a standardized method for equity and consistency. Thus, this study demonstrates the usefulness of fuzzy logic systems in decision-making processes, particularly in educational institutions. The system can be further developed by adding more selection criteria, combining it with existing school datasets, or applying the concept to other educational or organizational situations. This initiative thus lays a solid platform for future development in the pursuit of automated systems that prioritize fairness and efficiency.

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Declaration of Competing Interest

The authors declare no conflict of interest.

CRediT Authorship Contribution Statement

Wan Munirah Wan Mohamad (Conceptualisation)
Nurul Aishah Nadhirah Murad (Writing – review & editing)
Norbaiti Tukiman (Methodology)
Ahmad Khudzairi Khalid (Writing – original draft)
Nur Intan Syafinaz Ahmad (Methodology)
Nur Syamilah Arifin (Writing – review & editing)

Availability of the Data and Materials

The data used to support the findings of this study are included within the article.

Ethical Declarations

No artificial intelligence tools were used in the preparation of this manuscript. All content was developed manually by the authors. This study did not involve human participants or animals. Ethical approval was therefore not required.

Generative Artificial Intelligence Declarations

The authors claim that artificially intelligent-assisted technologies, such as generative AI, were not used to generate content, ideas, or theories. We have just utilized AI to enhance readability and refine the language. This was used with extreme human control and oversight. The authors take full responsibility for reviewing and approving the content.

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