Original Article

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# Prediction of Students' Major Selection Using the Fuzzy Sugeno Method Based on Report Card Grades

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**Abstract:**

This study aims to develop a student achievement prediction system based on the Fuzzy Sugeno method using average report card scores to support science or social studies specialization recommendations. The data were obtained from student report cards at SMA 1 Toho in Microsoft Excel format and processed through fuzzification, inference, and defuzzification stages using triangular membership functions to produce crisp values and achievement categories. The system was implemented using the Python programming language and evaluated for result consistency. The findings indicate that the Fuzzy Sugeno method can objectively predict student achievement and support data-driven decision making in determining student specialization.

**Keywords**: Student Achievement, Fuzzy Sugeno, Report Card Scores.

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## Introduction

Academic achievement is one of the key indicators used to assess students' academic potential. However, achievement is often viewed merely as numerical scores on report cards without being further utilized as a basis for academic decision-making, particularly in selecting specialization subjects at the senior high school level. As a result, many students choose inappropriate majors because decisions are based solely on teachers' intuition or personal preferences rather than objective analysis of academic performance data (Wahab & Fitri, 2021).

Various studies indicate that fuzzy logic is effective in supporting academic decision-making processes. The Sugeno method has been proven accurate in selecting outstanding students (Siregar & Kartika, 2023), effective in predicting the number of university students, and capable of producing consistent evaluation results in performance appraisal and service quality assessment (Mustika, 2021; Vinsensia, 2021). Furthermore, this method generates stable and measurable predictions in various numerical forecasting cases (Mustika, 2021).

This study differs from previous research by specifically utilizing students'

average report card grades as the basis for predicting academic achievement using the Sugeno fuzzy logic method. The predicted achievement results are then used as supporting information in providing recommendations for Science (IPA) or Social Studies (IPS) specialization. Thus, the resulting recommendation is not a final decision but rather a supporting consideration in the academic guidance process at SMA 1 Toho.

The Sugeno fuzzy logic method was selected because it can handle uncertainty, is relatively simple to implement, and produces crisp outputs that facilitate interpretation (Gozali, 2020). In addition, this method is well suited for numerical data such as report card grades.

This study seeks to design a student achievement prediction system based on students' average report card grades using the Sugeno fuzzy logic method. Furthermore, it examines how the predicted achievement results can be utilized to identify students' academic potential in selecting specialization subjects and how this information can serve as supporting input in recommending either the Science (IPA) or Social Studies (IPS) track.

This study aims to develop a Sugeno fuzzy logic–based decision support system to process students' report card grades, to generate academic achievement categories based on the fuzzy Sugeno method, and to provide Science (IPA) or Social Studies (IPS) specialization recommendations as supporting information for teachers in determining students' specialization choices.

## Literature Review

Previous studies show that the Fuzzy Sugeno method is effective in decision support systems for evaluating performance based on multiple criteria with high accuracy, using first-order inference to generate precise final decisions (Arieni, Halimah, & Audita, 2020). Comparative research between Fuzzy Mamdani and Fuzzy Sugeno in selecting outstanding students found similar outputs, but Sugeno was more efficient due to its crisp output, making it suitable for web-based systems (Siregar & Kartika, 2023).

Other studies applied Sugeno for predicting new student enrollment using historical data, producing acceptable forecasting accuracy for academic planning. Sugeno has also been used to measure service satisfaction levels based on perception and expectation data, demonstrating its ability to handle qualitative evaluations (Vinsensia, 2021). Additionally, it has been successfully implemented in numerical prediction systems such as commodity price forecasting, producing stable and accurate outputs (Mustika, 2021).

Based on these findings, this study applies the Fuzzy Sugeno method in education to predict student achievement using average report card grades as the main input variable. Data processing is conducted using Python and Microsoft Excel to generate measurable achievement categories and specialization recommendations.

### Subject Specialization Selection

Subject specialization at the secondary school level is a crucial academic decision that influences students' learning paths. Ideally, specialization decisions should be based on academic performance data, such as report card grades, to reduce subjectivity and improve placement accuracy (Hartati, 2023). However, many schools still rely on manual processes that do not comprehensively analyze performance patterns.

A data-driven approach, such as the Sugeno fuzzy method, enables the mapping of numerical grades into linguistic categories and produces flexible yet measurable specialization recommendations (Yusriyah & Retnasari, 2023). This approach aligns with modern curriculum demands that emphasize objective, evidence-based decision-making and helps reduce the risk of misplacement (Yuliyanti, Suryani, & Irnawan, 2020).

**Decision Support System (DSS)**

A Decision Support System (DSS) is a computer-based system designed to assist decision-making in complex problems using data and analytical models. In education, DSS supports major selection by analyzing academic ability and potential objectively (Harahap, Nasution, & Putri, 2025). Other DSS methods, such as Simple Additive Weighting (SAW), have also been applied for student placement decisions (Suryadijaya, 2018).

The Sugeno Fuzzy Inference System (FIS) offers flexibility in handling uncertain and diverse input data, producing accurate and adaptive outputs (Suryani, Husain, & Rauf, 2022; Zerlinda, Zaidan, Akifah, Devrida, & Sinaga, 2024). Its integration with data-based DSS enables automatic classification of student performance levels and consistent recommendation generation (Saut Panigoran Sihombing, Manalu, & Andani, 2024).

**Fuzzy Sugeno Logic**

The Sugeno (Takagi-Sugeno-Kang) model differs from Mamdani because its consequent is expressed as a constant or linear function, producing crisp outputs directly (Gozali, 2020). The process includes fuzzification, rule evaluation, inference, and weighted average defuzzification:

Average Report Card Formula:

$$\bar{x} = \frac{1}{m}\sum_{j=1}^{m} x_j$$

Sugeno Defuzzification Formula:

$$Z = \frac{\sum w_i z_i}{\sum w_i}$$

Sugeno's hybrid structure combining linguistic rules and mathematical models makes it widely applicable in education and other domains (Gozali, 2020).

1. Crisp Variables: Numerical inputs converted into fuzzy membership values during fuzzification (Pratiwi, Sari, & Widyasari, 2021; Firginia Astuti Sihombing, 2024; Wijaya & Putri, 2025).
2. Fuzzy Sets: Allow partial membership (0–1) to model uncertainty (Davvaz, Mukhlash, & Soleha, 2021).
3. Membership Functions: Typically triangular functions for simplicity and efficiency (Rahakbauw, 2015; Savitri & Suhaedi, 2022).

4. Fuzzy Rule Base: IF–THEN rules combining input variables to produce outputs (Rifai & Fitriyadi, 2023; Sugandi & Armentaria, 2021; Supriyatna, 2024).
5. Inference Process: Rule evaluation, consequent calculation, and aggregation to generate crisp output (Rahmat & Shaleh, 2025; Sitio, 2018; Yunita, Mayasari, & Rahman, 2025).
6. Defuzzification: Weighted average method producing stable numeric results (Asrianto & Effendi, 2022).

In this study, defuzzified outputs represent measurable student achievement levels used for specialization recommendations.

**Academic Data Processing**

Academic data processing involves cleaning, validating, and transforming report card grades to ensure accuracy before analysis (Wahab & Fitri, 2021). Proper preprocessing (handling missing values, duplicates, and outliers) improves prediction reliability and decision-making quality (Siregar & Kartika, 2023).

**Python in Data Processing**

Python is widely used in educational research due to its simplicity and powerful libraries such as NumPy and Pandas for numerical data processing (Mustika, 2021). It supports reading Excel data, calculating averages, implementing the Sugeno method, and visualizing results for clearer interpretation.

**Testing Technique**

System testing ensures reliability and consistency in generating recommendations (Cani, Hannie, & Ridha, 2023; Ridwan & Hendrik, 2024). Performance evaluation uses quantitative metrics such as the Confusion Matrix to measure accuracy, precision, and recall (Prasetyo & Nabiilah, 2023).

Accuracy is calculated as:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \times 100\%$$

Alternatively:

$$Accuracy = \frac{\text{Correct Predictions}}{\text{Total Samples}} \times 100\%$$

Sugeno is chosen because it produces consistent, objective, and traceable numerical outputs, reducing subjectivity compared to human decision-making (Yunita et al., 2025).

## Methods

**Research Stages**

This study consists of several main stages, beginning with report card grade processing as the primary data source. The data then undergo preprocessing and

transformation before being analyzed using the Fuzzy Sugeno method. The overall research workflow includes data collection, preprocessing, transformation, fuzzification, inference, defuzzification, classification, recommendation generation, system evaluation, and application implementation.

**Data Collection**

Data were collected through interviews with teachers at SMA Negeri 1 Toho to obtain permission and access to students' report card grades. The dataset, provided in Microsoft Excel format, consists of at least 100 student records to ensure adequate representation and stable fuzzy inference.

Only the average grades of eight subjects were used: Mathematics, Biology, Physics, Chemistry, History, Geography, Sociology, and Economics. Other variables such as attendance, student ID numbers, religious subjects, and extracurricular scores were excluded to maintain analytical focus and reduce noise.

**Data Preprocessing**

Preprocessing was conducted to filter and restructure the dataset. Irrelevant columns and 18 non-related subjects were removed. The final dataset retained only the eight selected subjects relevant to Science (IPA) and Social Studies (IPS) specialization. This process ensured structured, consistent, and analysis-ready data.

**Data Transformation**

In this stage, subject grades were processed to produce representative academic performance values. Grades remained within the 0–100 scale and were prepared as numerical inputs for fuzzification. The transformed output served as the input variable in the Sugeno fuzzy system.

**Fuzzification**

Fuzzification converts crisp numerical grades into fuzzy membership values. Four linguistic categories were defined: Low, Fair, Good, and Very Good.

Triangular membership functions were applied as follows:

$$\mu(x) = 0 \quad \text{if } x \leq a \text{ or } x \geq c$$

$$\mu(x) = \frac{x - a}{b - a} \quad \text{if } a < x < b$$

$$\mu(x) = \frac{c - x}{c - b} \quad \text{if } b < x < c$$

$$\mu(x) = 1 \quad \text{if } x = b$$

Where:

1. $\mu(x)$ = degree of membership (0–1)
2. $x$ = crisp value
3. $a$ = lower bound
4. $b$ = peak
5. $c$ = upper bound

Each subject grade was treated as an independent crisp variable, allowing detailed academic strength analysis rather than relying solely on a single average score.

**Defuzzification**

Defuzzification was performed using the Sugeno weighted average method. Each fuzzy rule produces a crisp output value, which is combined using:

$$Z = \frac{\sum w_i z_i}{\sum w_i}$$

The final result is a numerical prediction of academic achievement.

**Achievement Categorization**

The defuzzified value was classified into achievement levels:

1. < 40 = Low
2. 40–59 = Fair
3. 60–79 = Good
4. ≥ 80 = Very Good

This categorization forms the basis for specialization recommendations.

**Major Recommendation Determination**

Major recommendations were generated automatically based on academic prediction results and subject dominance.

1. If dominant performance lies in Mathematics, Biology, Physics, and Chemistry → Science (IPA)
2. If dominant performance lies in History, Geography, Sociology, and Economics → Social Studies (IPS)
3. If balanced → Manual Evaluation Required

The recommendation serves as decision support, not as a final determination.

**System Evaluation**

System evaluation assessed the correctness of the Sugeno calculation process and the consistency of prediction results. Outputs were compared with reference data to verify system reliability across preprocessing, transformation, fuzzification, defuzzification, and recommendation stages.

**Application Implementation**

The designed Sugeno fuzzy method was implemented into a GUI-based application. The system automatically:

1. Loads Excel data
2. Validates structure
3. Calculates averages
4. Performs fuzzification and Sugeno inference
5. Executes weighted average defuzzification
6. Classifies achievement
7. Generates major recommendations
8. Displays and exports results to Excel

The application ensures consistent and automated execution of the Sugeno logic, bridging theoretical design and practical academic decision support.

## Results

### System Implementation Results

The results of the system implementation in this study were obtained from testing the Sugeno application using students' report card grades in Microsoft Excel format. The data used were preprocessing and transformation results as explained in Chapter III, consisting of eight main subjects: General Mathematics, Biology, Physics, Chemistry, History, Geography, Sociology, and Economics. After the data were loaded into the application, the system successfully processed all student data without errors and generated the average score, the fuzzy Sugeno calculation result (crisp value), and the student achievement category.

Based on the processing results, the system was able to classify student achievement into four categories: Poor, Fair, Good, and Very Good. In addition, the application produced recommendations for Science (IPA) or Social Sciences (IPS) majors based on subject grades and rules defined in the fuzzy Sugeno model. All testing results were displayed in tabular form containing complete information on student grades, achievement categories, major recommendations, and the reasoning behind the system's decision. These results indicate that the AppSugeno application consistently implements the fuzzy Sugeno method and produces outputs aligned with the research objective, namely assisting in evaluating student achievement and supporting objective decision-making for major selection.

### Main Page Display

The Sugeno application has a single main page that serves as the center of all system activities in processing and testing student report card data. This main page is the initial interface when the application is launched and is the only page used by users to load data, execute the fuzzy Sugeno process, and view achievement predictions and major recommendations. The interface is designed to be simple and integrated so that all processes can be completed in a single workflow aligned with the research objectives.

The main page includes several control buttons arranged sequentially, each with specific functions supporting data processing. The Load Excel button is used to load a Microsoft Excel file containing student report card grades as system test data. After the data are successfully loaded, the Process & Display button runs the fuzzy Sugeno calculation process, including calculating the average score, determining the crisp value, classifying achievement categories, and recommending the Science (IPA) or Social Sciences (IPS) major.

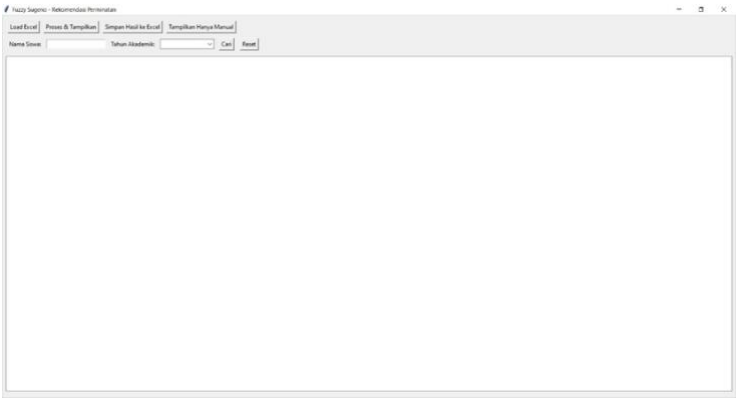

Figure 1. Main Page

Next, the Save Results to Excel button allows users to save the processed results into an Excel file for documentation or further analysis.

In addition to these main buttons, the application provides a Show Rules button to display the IPA and IPS specialization rules used by the system, as well as a Show Manual Only button to display student data requiring further evaluation if the recommendation cannot be determined automatically. All processed results are displayed in table format on the same page, enabling users to directly view the structured system output.

**System Input and Output Flow**

The workflow of the Sugeno application consists of three main parts: data input, data processing, and system output. These parts describe how student report card grades are processed to generate achievement predictions and major recommendations.

1. Data Input

   The system input consists of student report card grades loaded in Microsoft Excel format. The input data contain grades for eight main subjects: General Mathematics, Biology, Physics, Chemistry, History, Geography, Sociology, and Economics. These data are arranged in a standardized tabular format ready for system processing. The grades serve as the basis for calculating the student's average score and as evaluation parameters in the specialization recommendation process.

2. Data Processing

   Data processing is the core part of the system, where the fuzzy Sugeno logic method is applied. After loading the input data, the system first calculates each student's report card average based on all available subject grades. This average represents the initial academic performance level of the student.

   Next, the average score is processed using the fuzzy Sugeno method through fuzzification, inference, and defuzzification stages.

   a. In the fuzzification stage, the average score is mapped into membership degrees across several achievement categories.
   b. The fuzzification results are then used in the inference process to determine the contribution level of each rule.
   c. In the final stage, the system performs defuzzification to produce a crisp value representing the student's academic performance numerically.

Based on the resulting crisp value, the system classifies student achievement into Poor, Fair, Good, or Very Good categories. Additionally, the system evaluates specific subject grades using predefined rules to determine recommendations for Science (IPA) or Social Sciences (IPS). If specialization rules are satisfied, the system directly generates a recommendation. Otherwise, the system compares calculation results to determine the most appropriate recommendation. This mechanism ensures systematic and consistent decision-making.

3. System Output

The system output consists of processed data displayed in tabular form within the application. The information includes the student's average score, fuzzy Sugeno crisp value, achievement category, major recommendation (IPA or IPS), and the reasoning behind the system's decision. All outputs can also be saved to an Excel file for documentation and further analysis.

**System Testing**

System testing was conducted to ensure that fuzzification, inference, and defuzzification processes in the Fuzzy Sugeno method operated according to the system design and application implementation. Testing used student report card data, focusing on one student sample for detailed calculation verification.

The testing process began by calculating the student's average grade from the eight main subjects. The average was then fuzzified into four achievement categories—Poor, Fair, Good, and Very Good—using triangular membership functions. The resulting membership degrees were processed through Sugeno inference and weighted average defuzzification to produce the crisp achievement value and final achievement category.

In addition to academic performance testing, the system was tested for specialization subject determination by applying fuzzification and Sugeno calculations to each Science (IPA) and Social Sciences (IPS) subject grade. The crisp Sugeno value of each subject served as the basis for rule-base implementation and selection of two primary interest subjects (Interest 1 and Interest 2) for each major.

Testing results showed that the system consistently and systematically generated achievement values, achievement categories, interest subject recommendations, and major recommendations according to the implemented calculation logic.

**Academic Achievement Fuzzification**

Testing of academic achievement fuzzification was conducted using data from student number 1, ALING, taken from the file Data Input.xlsx.

Aling's subject grades were:

1. General Mathematics: 85
2. Biology: 88
3. Physics: 91
4. Chemistry: 83
5. History: 92
6. Geography: 94
7. Sociology: 90
8. Economics: 95

The first step was calculating the average score:

$$\bar{x} = \frac{85 + 88 + 91 + 83 + 92 + 94 + 90 + 95}{8} = 89.75$$

The average value of 89.75 was used as the crisp input for fuzzification. Using triangular membership functions:

1. Poor (0, 20, 45) → μPoor(89.75) = 0
2. Fair (30, 47.5, 65) → μFair(89.75) = 0
3. Good (55, 70, 85) → μGood(89.75) = 0
4. Very Good (75, 87.5, 100)

Since 89.75 lies between 87.5 and 100:

$$\mu_{VeryGood}(x) = \frac{100 - 89.75}{100 - 87.5}$$

$$\mu_{VeryGood}(89.75) = \frac{10.25}{12.5} = 0.82$$

Thus, only the Very Good category has an active membership degree of 0.82.

**Academic Achievement Defuzzification**

Using zero-order Sugeno singleton outputs:

1. Poor = 25
2. Fair = 50
3. Good = 75
4. Very Good = 100

Defuzzification formula:

$$Z = \frac{\sum(\mu_i \times z_i)}{\sum \mu_i}$$

$$Z = \frac{0.82 \times 100}{0.82} = 100$$

Thus, Aling's crisp academic achievement value is 100, categorized as Very Good (≥ 80).

**Sugeno Calculation for Specialization Subjects**

Science (IPA) Subjects:

Table 1. Sugeno's Grades in Science Subjects

| Subject | Score | Sugeno Value |
|---|---|---|
| Mathematics | 85 | 100 |
| Biology | 88 | 100 |

| | | |
|---|---|---|
| Physics | 91 | 100 |
| Chemistry | 83 | 75 |

Social Sciences (IPS) Subjects:

Table 2. Sugeno's Scores for Social Studies Subjects

| Subject | Score | Sugeno Value |
|---|---|---|
| History | 92 | 100 |
| Geography | 94 | 100 |
| Sociology | 90 | 100 |
| Economics | 95 | 100 |

**Rule-Based Interest Subject Selection**

Subjects are grouped into IPA and IPS. The system applies IF–THEN rules combining two subjects with certain achievement categories. The rule activation degree is calculated using the minimum operator, and the highest activation rule determines the interest subjects.

If no rule is active, the system selects the two highest Sugeno values within the same major.

For student ALING:

1. IPS: Economics (Interest 1), Geography (Interest 2)
2. IPA: Physics (Interest 1), Biology (Interest 2)

**Major Recommendation Determination**

The system could not automatically determine whether ALING should choose IPA or IPS because the accumulated Sugeno values for both majors were equally high and relatively balanced.

Since no significant difference was found between IPA and IPS, the system produced the recommendation: Manual Evaluation Required.

This indicates that the student does not show clear academic dominance in one major. Therefore, final major determination should consider additional factors such as student interest and teacher recommendations beyond report card grades.

## Conclusion

Based on the results of the system design, implementation, and testing that have been conducted, it can be concluded that the decision support system for selecting academic achievement and interest subjects using the Fuzzy Sugeno method has been successfully developed and implemented in accordance with the research objectives.

The system is capable of processing students' report card grades, performing fuzzification and defuzzification of academic achievement, and automatically generating achievement categories consistently with manual calculations. In addition, the system can calculate the Sugeno value for each interest subject and apply rule-based reasoning to determine interest subjects as well as recommendations for Science (IPA) or Social Sciences (IPS) majors.

The testing results indicate that the system outputs are consistent with the implemented calculation logic and rules within the Sugeno application and align with the expected results generated by the system.

**Suggestions**

Based on the research that has been conducted, several suggestions can be proposed for further development. The system can be improved by adding additional evaluation variables beyond report card grades, such as students' interests or aptitude test results, in order to produce more comprehensive major recommendations.

Furthermore, the system can be enhanced by incorporating comparisons with other decision-making methods for evaluation purposes, as well as conducting testing using larger and more diverse datasets to assess the system's performance more extensively.

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