# Dissertation on
# Students' Academic Performance Evaluation Using Fuzzy System – An Approach

*Thesis submitted towards partial fulfilment*
*of the requirements for the degree of*

**Master of Technology in IT (Courseware Engineering)**

*Submitted by*
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This is to certify that the thesis entitled **"Students' Academic Performance Evaluation Using Fuzzy System – An Approach"** is a bonafide work carried out by **IMAN DATTA GUPTA** under our supervision and guidance for partial fulfilment of the requirements for the degree of Master of Technology in IT (Courseware Engineering) in School of Education Technology, during the academic session 2023-2024.

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# CONTENT


| Topic Name | Page No. |
|---|---|
| List of Figures | vii |
| List of Tables | viii |
| Publication | ix |
| Executive Summary | x |
| Chapter 1: | 1-3 |
| 1. Introduction | 2-3 |
| 1.1 Overview | 2 |
| 1.2 Problem Statement | 2 |
| 1.3 Research Questions | 3 |
| 1.4 Objectives | 3 |
| Chapter 2: | 4-9 |
| 2. Basic Concepts | 5-9 |
| 2.1 Fuzzy Logic | 5 |
| 2.2 Fuzzy set theory | 5 |
| 2.3 Membership Functions | 5 |
| 2.3.1 Types of membership functions | 6 |
| 2.4 Fuzzy System | 7 |
| 2.4.1 Types of Fuzzy Inference system | 7 |
| 2.4.2 Advantages of Fuzzy System | 8 |
| 2.4.3 Disadvantage of Fuzzy System | 8 |
| 2.4.4 Applications of Fuzzy System | 8-9 |
| 2.4.5 Fuzzy Operators and Reasoning | 9 |
| Chapter 3 : | 10-14 |
| 3. Literature Review | 11-14 |
| Chapter 4 : | 15-18 |
| 4. Proposed Approach | 16 |
| 4.1 Software Description | 16 |
| 4.2 Dataset Description | 16 |
| Chapter 5 : | 19-40 |
| 5. Experimentations and Results | 20-40 |
| 5.1 Yadav and Singh method | 20-30 |
| 5.1.1 Implementation of Yadav and Singh Method | 20-30 |
| 5.2 Existing Method | 30-35 |
| 5.2.1 Implementation of Existing Method | 30-35 |
| 5.3 Proposed Modified Method | 35-40 |
| 5.3.1 Implementation of Proposed Modified Method | 35-40 |

| | |
|---|---|
| Chapter 6 : | 41-52 |
| 6. Comparative Analysis | 42-52 |
| 6.1. Discussion | 49-52 |
| Chapter 7 : | 53-54 |
| 7.1 Conclusion | 54 |
| 7.2 Future Scope | 54 |
| References | 55-57 |
| Appendix A | 58 |
| Appendix B | 59-74 |

## List of Figures


| Serial No. | Figure Name | Page No. |
|---|---|---|
| 1. | Figure 1: Fuzzy membership function | 6 |
| 2. | Figure 2: Types of membership function | 6 |

## List of Tables


| Serial No. | Table Name | Page No. |
|---|---|---|
| 1. | Table 1: Dataset used in the research work | 18 |
| 2. | Table 2: Fuzzy set of input variable for semester-1 in Fuzzy-1 Method | 20 |
| 3. | Table 3: Fuzzy set of input variable for semester-2 in Fuzzy-1 Method | 20 |
| 4. | Table 4 : Fuzzy set of output variable for Performance Value in Fuzzy-1 Method | 21 |
| 5. | Table 5: Output Performance Value obtained by Fuzzy-1 Method | 23 |
| 6. | Table 6: Fuzzy set of input variable for semester-1 in Fuzzy-2 Method | 24 |
| 7. | Table 7: Fuzzy set of input variable for semester-2 in Fuzzy-2 Method | 24 |
| 8. | Table 8 : Fuzzy set of output variable for Performance Value in Fuzzy-2 Method | 24 |
| 9. | Table 9 : Output Performance Value obtained by Fuzzy-2 Method | 27 |
| 10. | Table 10: Fuzzy set of input variable for semester-1 in Existing Method | 28 |
| 11. | Table 11: Fuzzy set of input variable for semester-2 in Existing Method | 28 |
| 12. | Table 12 : Fuzzy set of output variable for Performance Value in Existing Method | 28 |
| 13. | Table 13 : Output Performance Value obtained by Existing Method | 30 |
| 14. | Table 14 : Fuzzy set of input variable for semester-1 in Proposed Modified Method | 31 |
| 15. | Table 15 : Fuzzy set of input variable for semester-2 in Proposed Modified Method | 31 |
| 16. | Table 16 : Fuzzy set of output variable for Performance Value in Proposed Modified Method | 31 |
| 17. | Table 17 : Output Performance Value obtained by Proposed Modified Method | 34 |
| 18. | Table 18: Comparison of classical average method, Yadav and Singh Method, existing method and proposed modified method. | 36-37 |

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# EXECUTIVE SUMMARY

Students' academic performance evaluation is the measurement of their improvement and deterioration in study. Calculating average marks of examinations for students' performance evaluation is well accepted by many educational institutions around the world. But this method does not reward or penalize the students by giving any extra or less marks or qualify or disqualify them based on their improvement or deterioration in study to motivate or alert them. It is found that methods based on fuzzy logic are able to reward or penalize a student based on his/her improvement or deterioration in study by giving extra or less marks or qualifying or disqualifying him/her. To verify that, an existing fuzzy system is implemented and compared with the classical average method and Yadav and Singh method and found more suitable. But it is found that in some cases, the student is penalized or not rewarded for the improvement in study in the existing fuzzy system. So, the existing fuzzy system is modified by changing the "IF-THEN" rules and the new rules are found more suitable for students' performance evaluation. The aim of the proposed modified method is to improve the performance of the existing method with the help of suitable fuzzy rules. In the existing method, the results were validated by the researchers using MATLAB fuzzy logic toolbox but in this research work the results are validated by using python3, with Simpul which is a user-friendly open-source python library for fuzzy logic. Simpful is user-friendly as the fuzzy rules are written in natural language. Cloud based coding platform Google Colab is used in this research work.

# Chapter 1

# 1. Introduction

## 1.1 Overview

Students' academic performance is the measurement of their mastery in a subject matter, their level of intelligence, progress in study and their weaknesses by measuring their scores. Student's academic performance evaluation is very important because it can be helpful for the students who need to improve their academic performance. Traditional method for students' academic performance evaluation is accepted by many educational institutions around the world. But that method has its own limitations. Let's consider a case where two students score 50, 70 and 70, 50 out of 100 in their two semesters. The average mark obtained by each of the students is 60. From this, can it be concluded that the level of intelligence of both the students is the same? Obviously not! It is clear that one student is improving in his/her study where the other is deteriorating. This current study is about to argue that the current arithmetical method is not the best way for students' academic performance evaluation and methods based on fuzzy logic are suitable to reward or penalize a student based on their improvement or deterioration in study. A modified fuzzy rule-based system is proposed for students' academic performance evaluation where the modification is based on fuzzy rules of an existing method. The aim of this research work is to improve the existing method with fuzzy reasoning, also known as approximate reasoning, based on fuzzy rules that are expressed in natural language, the way people think and make judgements. This additional information will help the user for decision making. The method can be applied to Computer Assisted Instruction.

## 1.2 Problem Statement

"A suitable fuzzy rule based system is needed which will be able to reward or penalize a student based on their improvement or deterioration in study by giving extra or less marks or qualifying or disqualifying them which classical average method is unable to offer."

## 1.3 Research Questions

The study aimed to address the following research questions:

1. What is the difference in assessment results between classical and fuzzy logic evaluation methods?

2. What is the difference in assessment results between fuzzy rule based evaluation methods?

3. What is the difference in assessment results between the modified method and the existing method?

## 1.4 Objectives

1.To apply fuzzy modelling based on previous and new data for evaluation of students' academic performance.

2.To find a suitable fuzzy rule based system which will be able to reward or penalize a student based on their improvement or deterioration in study by giving extra or less marks or qualifying or disqualifying them which classical average method is unable to offer.

# Chapter 2

## 2. Basic Concepts

### 2.1 Fuzzy Logic

Fuzzy logic is a branch of logic specially designed for representing knowledge and human reasoning in such a way that it is open and responsive to suggestion, easily controlled to processing by a computer. Thus, it is applicable to artificial intelligence, control engineering, and expert systems . Fuzzy logic was first introduced by Lofti A. Zadeh, professor of Computer Science at University of California in Berkeley in 1965. In traditional evaluation methods results generally have binary or Boolean values like true/false, yes/no, high/low, 0/1 etc which are called crisp values. But there may be several cases or situations where the values may not be crisp. For example, an answer to a question may not always be either correct or wrong. Answers may be very good, good, average, poor or very poor. That is, the range is 0-1.

### 2.2 Fuzzy Set Theory

Fuzzy set theory is built on partial memberships. For example, an individual is a 0.65 member of a set or an action is 75% true, where the traditional set theory is based on if a value absolutely belongs to a set or not, such as "0 or 1"," false or true", and "good or bad".

### 2.3 Membership Functions

Fuzzy sets are determined by membership functions. The membership function of a fuzzy set is expressed as $\mu\bar{A}(x)$ and membership degree of its fuzzy set is determined as a number between 0 and 1. If factor x definitely belongs to set $\bar{A}$, $\mu\bar{A}(x)$ is 1 and if it definitely does not belong to set $\bar{A}$, $\mu\bar{A}(x)$ is 0. A higher membership function value (up to a value of 1) shows that factor x has a stronger degree of membership to set $\bar{A}$.

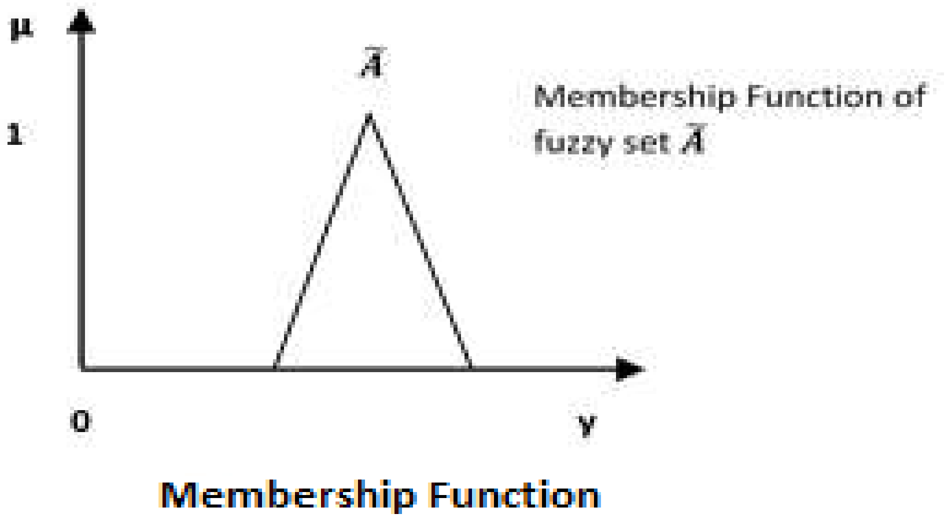


**Figure 1:** Fuzzy membership function[24]

### 2.3.1 Types of Membership Functions

1) Triangular membership function

2) Trapezoidal membership function

3) Gaussian membership function

4) Generalized bell membership function

5) Sigmoid membership function

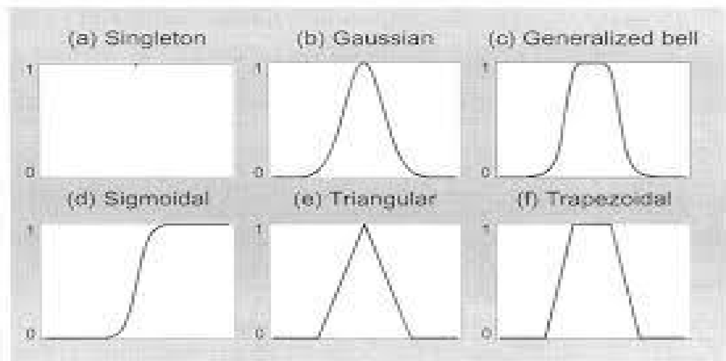


**Figure 2:** Types of membership function[25]

## 2.4 Fuzzy System

Fuzzy system which is also known as Fuzzy logic system or Fuzzy Inference System is the system which is used to implement the fuzzy set. At first, crisp value (here student mark) is converted into fuzzy input value with the help of any membership function. This process is called fuzzification.

Then a suitable "IF THEN" rule is defined. At last, the fuzzy values are converted into crisp values and the final output is obtained. This is called defuzzification which is the opposite process of the fuzzification method. Main elements of fuzzy logic system are:

1) Fuzzifier : Converts crisp values into fuzzy values. Machines cannot understand crisp values so they are converted to fuzzy values.

2) Fuzzy rule : Suitable "IF-THEN" rule is defined according to the requirement to convert crisp values into fuzzy values.

3) Defuzzifier : Converts fuzzy values into crisp values for human understanding.

### 2.4.1 Types of Fuzzy Inference System

There are two types of Fuzzy inference system on which the fuzzy logic can be implemented:

a) Mamdani type fuzzy inference
b) Sugeno type fuzzy inference

#### 2.4.1.1 Mamdani Type of Fuzzy Inference System

Mamdani type is the most commonly used inference system. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination.

In the Mamdani type of inference system, both the input and the output are expressed in the form like very good, good, average, poor, very poor.

Here fuzzy rules are defined in the form: If a is b, then x is y.

#### 2.4.1.2 Sugeno Type of Fuzzy Inference System

The Sugeno type fuzzy inference system was first introduced in 1985. The main difference between Sugeno and Mamdani is the output membership function.

Here rules are in the form: If x is a, then y is f(x).

### 2.4.2 Advantages of Fuzzy System

1) Easy to understand .

2) The implementation of Fuzzy Inference Systems is easy and understandable.

3) Fuzzy rules are written in natural language.

4) Best method to deal with uncertain problems.

5) It is simple as it is based on the set theory of mathematics.

6) Requires less time for implementation.

7) Rules can be easily edited and deleted in the inference system.

### 2.4.3 Disadvantage of Fuzzy System

Need a lot of testing for verification and validation.

### 2.4.4 Applications of Fuzzy System

1) It is used in the aerospace field for altitude control of spacecraft and satellites.

2) Used in the automotive system for speed control, traffic control.

3) Used for decision-making support systems and personal evaluation in the large company business.

4) Fuzzy logic has application in the chemical industry for controlling the pH, drying, chemical distillation process.

5) Used in Natural language processing and various applications in Artificial Intelligence.

6) Extensively used in modern control systems such as expert systems.

### 2.4.5 Fuzzy Operators and Reasoning

AND, OR and NOT operators are commonly used operators in fuzzy-rule based systems. Among them, AND operator is mostly used. In fuzzy logic, fuzzy reasoning, also known as approximate reasoning, is based on fuzzy rules that are expressed in natural language, the way people think and make judgments. A fuzzy rule has the form: If $x \in A$ and $y \in B$ then $z \in C$, with A, B and C fuzzy sets. For example: "If (the quality of the food is delicious), then (tip is high)".

# Chapter 3

## 3. Literature review

[1] In this research paper, a new fuzzy expert system is proposed for students' academic performance evaluation based on fuzzy logic techniques. The classical method, fuzzy-1 and fuzzy-2 and the proposed method are compared. It is observed that the proposed method is more suitable for students' performance evaluation. In fuzzy-1 scenario, all the membership functions are the same for both the semester examinations, whereas in fuzzy-2 scenario membership functions for semester-2 examination are modified.

[2] In this research paper, the classical method, fuzzy-1 and fuzzy-2 method are compared. It is observed that the fuzzy logic method is more suitable than the classical method. In the fuzzy-1 scenario, all the membership functions are the same for both the semester examinations where in fuzzy-2 scenario membership functions for semester-2 examination are modified.

[3] In this research paper, a new performance evaluation method is proposed based on fuzzy logic systems. Student performance of Control Technique Laboratory in Marmara University Technical Education Faculty, Electricity Education Department, was carried out with fuzzy logic and it was compared with classical evaluation methods. The dataset consists of twenty students' marks who took the control technique laboratory course. It is observed that the fuzzy logic method is more suitable than the classical method.

[4] In this research paper, the crisp values of a clinical dataset is converted into fuzzy values by using triangular membership function and trapezoidal membership function. The fuzzification process produced fuzzified values that help to find more knowledge and avoid complexity of data classification process. The performance of trapezoidal membership function is found better than triangular membership function.

[5] In this research paper, the machine learning algorithm linear regression is implemented to predict the student's academic performance. Authors found that the academic performances of the students are dependent on the student's background and other attributes.

[6] In this research paper, the fuzzy logic based python library named simpful is proposed. Here fuzzy rules are written in natural language. This python library is found more user-friendly than other python libraries for fuzzy logic. It

supports both Mamdani and Sugeno fuzzy inference systems. To show its usage, three examples are provided: the implementation of the tipping problem, the implementation of a clinical decision support system to diagnose sepsis, and the modeling and simulation of a complex biochemical system by means of a dynamic fuzzy model.

[7] This research paper is focused on the performance analysis of engineers using Fuzzy Logic based evaluation methods. The results are validated by using MATLAB software. The results show that the fuzzy approach was close to the results obtained by classical average method but with more accuracy. If a student scores less in examination i.e. 12 still his overall rating is higher using average method i.e. 29.01 but using the fuzzy approach the overall rating is reduced to 25 points. The research objectives of obtaining a fuzzy reasoning based MATLAB-Simulink model for performance evaluation of students has been achieved.

[8] In this research work, the author found seven parameters: Homework, Quiz, Middle Examination, Final Examination, Video lessons, Read E- books, and Virtual Class Attendance that very much affect digital learning, enhancing accuracy as compared to using only one limited parameter. At last, results are validated by using Fuzzy System with MATLAB Fuzzy logic toolbox.

[9] In this research paper an approach for overall evaluation of a student's performance has been described. The result obtained by the proposed methodology has shown a high performance of it. Based on the results, it can be concluded that the fuzzy approach is much more effective than the classical aggregate approach. The fuzzy approach can be used to balance the performance between the internal assessment and final examination. In the classical approach a poor performance in one component was overlooked given a better performance in the other component. Here also results are validated by using the Fuzzy Inference System with the MATLAB Fuzzy tool.

[10] In this research paper authors review the available avenues of distance learning and offer a model that they prepared as an example of web-based distance learning and training. This model combines video-conferencing, interactive classroom, web-based lectures and traditional instructions in an optimized way to achieve the goal of high-quality technical education. Author presents this hybrid learning model and discusses the opportunities and challenges of web technologies in the education of Computer Science and

Engineering. Some suggestions like mini lecture technique, group discussion and surprise questions to overcome the problem of students of public speaking, online discussion forums to help the students in study by uploading questions and to also discuss personal hobbies for motivation purpose, hands-on experiments by applications like Java applet, detecting Plagiarism by Moss Tool are presented. A sample academic program in computer information systems is developed which is being implemented as a distance program at SUNY Fredonia.

[11] This research paper reviewed traditional instructional design models and compared them to instructional delivery strategies in Internet instruction, identifying a hybrid design model that merged step-by-step and objectivist methodologies with flexible design and constructivist strategies. This integrated model maintains the procedural elements and enables opportunities for revisions throughout development and delivery of instruction.

[12] In this research paper authors found that perceptions about online learning differ in students who have participated in prior online courses from those who have not participated in online courses. To collect data focusing on student perceptions of online learning, pre-course and post-course electronic surveys were conducted to both student populations (Both online and face-to-face students). Thirty-five responses were received out of fifty-one. The findings of this study suggest that the face-to-face students were less confident than the online students in their ability to succeed in the online format and felt they would do better in a traditional classroom setting with fewer than of the population (70%) expecting to do somewhat to very well before the course and slightly more than of the population (77%) at the end of the course before grades were assigned. Authors suggest that Offering hybrid courses might provide an attractive solution to the less mature learner, for example, face-to-face class meetings periodically throughout the semester might provide the opportunity for the less mature learner to succeed by lending enough support to offset the "loneliness of the distance learner."

[13] This research paper provides a comparative analysis across three countries whose institutions of higher education do not have large offerings in distance education. The result of this study provides some strategies to encourage and support students to take distance education courses. Online survey was conducted at Institutes of Higher Education in three countries Portugal, UAE (United Arab Emirates) and Ukraine. This survey consists of 10 MCQ type

questions. Authors conclude that further development of DE courses and programs at Institutes of Higher Education in countries such as UAE, Portugal and Ukraine have good prospects. The students' primary concerns regarding taking DE courses were almost similar among the three countries. Recommendations by the authors:

• Provide Pre-DE courses to build skills and behaviours based on students' concerns.

• Train instructors to develop and deliver DE courses that help to overcome obstacles such as motivation.

[14] In this research paper, a fuzzy logic based MATLAB-Simulink model is proposed for academic performance evaluation of students. The results show the advantages of the proposed method over the traditional average method. The fuzzy reasoning approach provides an additional advantage of allocating different weightage to each attribute according to needs and requirements of the organization. Therefore, for very low academic marks 30, 90, 90, 90 the overall rating using average approach is 78 which is very large as compared to fuzzy approach i.e. 69.06. It also observed that the results of the fuzzy approach are close to the results evaluated by the average method for almost all the experiments. Thus the fuzzy model closely mimics the behaviour of the traditional average method used for student performance evaluation.

[15] The performance of a student depends on two major factors: one is the examination marks and other is the number of classes that he/she attended i.e. attendance. This research paper presents a methodology to improve these two factors. The whole data i.e. obtained marks and attendance is divided into various ranges. This can be easily done by a fuzzy logic system. Proposed methodology is found very useful to analyze the performance of students. The improvement methodology can be applied to those students that are under the performance category of 'poor' or 'very poor'. This improvement methodology varies from institution/university to institution/university.

# Chapter 4

## 4. Proposed Approach

At first, the existing method is implemented and compared with the classical average technique. Then the existing fuzzy system is modified by changing the "IF-THEN" rules. In this research work the results are validated by using python3, Simpful which is a user-friendly open-source python library for fuzzy logic is used. Cloud based coding platform Google Colab is used in this research work.

### 4.1 Software Description

Simpful is a user-friendly Python library used to implement fuzzy inference systems. Simpful provides a lightweight Application Programming Interface that defines fuzzy sets and fuzzy rules. In Simpful, fuzzy rules are written in natural language. Software libraries and toolboxes that are capable of handling fuzzy logic are limited in number, and are often outdated or not open-source. To overcome the problem, a user-friendly Python library Simpful is used to implement fuzzy systems in this research work.

### 4.2 Dataset Description

The entire dataset is a combination of the dataset of the existing research work and a self-created dataset. There are 41 samples in the dataset where the first 21 samples are from the dataset of the existing research work and the remaining 20 samples are obtained by swapping the sem-1 and sem-2 scores of the dataset.

**Table 1:** Dataset used for the research work

| Serial No. | Sem-1 | Sem-2 |
|---|---|---|
| 1. | 40 | 65 |
| 2. | 20 | 35 |
| 3. | 50 | 65 |
| 4. | 10 | 20 |
| 5. | 45 | 65 |
| 6. | 34 | 60 |
| 7. | 48 | 55 |
| 8. | 56 | 90 |
| 9. | 74 | 70 |
| 10. | 45 | 50 |
| 11. | 65 | 45 |
| 12. | 89 | 100 |
| 13. | 100 | 100 |
| 14. | 65 | 35 |
| 15. | 48 | 50 |
| 16. | 45 | 55 |
| 17. | 55 | 25 |
| 18. | 84 | 80 |
| 19. | 63 | 65 |
| 20. | 28 | 30 |
| 21. | 65 | 40 |
| 22. | 35 | 20 |
| 23. | 65 | 50 |
| 24. | 20 | 10 |
| 25. | 65 | 45 |
| 26. | 60 | 34 |

| | | |
|---|---|---|
| 27. | 55 | 48 |
| 28. | 90 | 56 |
| 29. | 70 | 74 |
| 30. | 50 | 45 |
| 31. | 45 | 65 |
| 32. | 100 | 89 |
| 33. | 35 | 65 |
| 34. | 50 | 48 |
| 35. | 55 | 45 |
| 36. | 25 | 55 |
| 37. | 80 | 84 |
| 38. | 65 | 63 |
| 39. | 30 | 28 |
| 40. | 50 | 39 |
| 41. | 70 | 66 |

# Chapter 5

## 5. Experimentations and Results

### 5.1 Yadav and Singh Method

Yadav and Singh proposed two methods based on fuzzy logic which are called fuzzy-1 and fuzzy-2. In fuzzy-1 scenario, all the membership functions are the same for both the semester examinations, but in fuzzy-2 scenario membership functions for semester-2 examination are modified.

### 5.1.1 Implementation of Yadav and Singh Method

#### 5.1.1.1 Implementation of Fuzzy-1 Method

Fuzzy Inference System used for the Implementation:

Mamdani type Fuzzy Inference System.

Membership Function used:

Triangular membership function.

**Table 2:** Fuzzy set of input variable for semester-1 in Fuzzy-1 Method

| Linguistic Variable | Interval |
|---|---|
| verylow | (0,0,25) |
| low | (0,25,50) |
| medium | (25,50,75) |
| high | (50,75,100) |
| veryhigh | (75,100,100) |

**Table 3:** Fuzzy set of input variable for semester-2 in Fuzzy-1 Method

| Linguistic variable | Interval |
|---|---|
| verylow | (0,0,25) |
| low | (0,25,50) |
| medium | (25,50,75) |
| high | (50,75,100) |
| veryhigh | (75,100,100) |

**Table 4:** Fuzzy set of output variable for performance value in Fuzzy-1 Method

| Linguistic variable | Interval |
|---|---|
| verylow | (0,0,25) |
| low | (0,25,50) |
| medium | (25,50,75) |
| high | (50,75,100) |
| veryhigh | (75,100,100) |

Membership function for semester-1 in Fuzzy-1 Method:

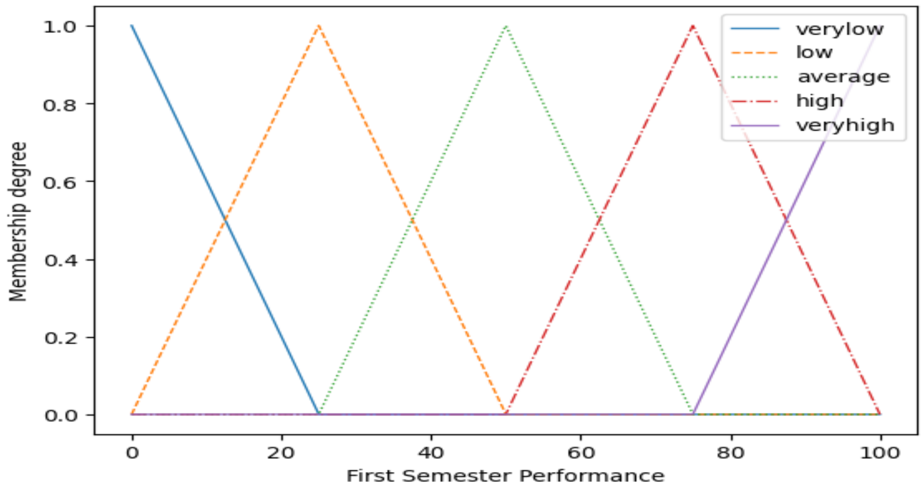


**Figure 3:** Membership function for semester-1 in Fuzzy-1 Method

(Source: Self-Created in Google Colab)

Membership Function for semester-2 in Fuzzy-1 Method:

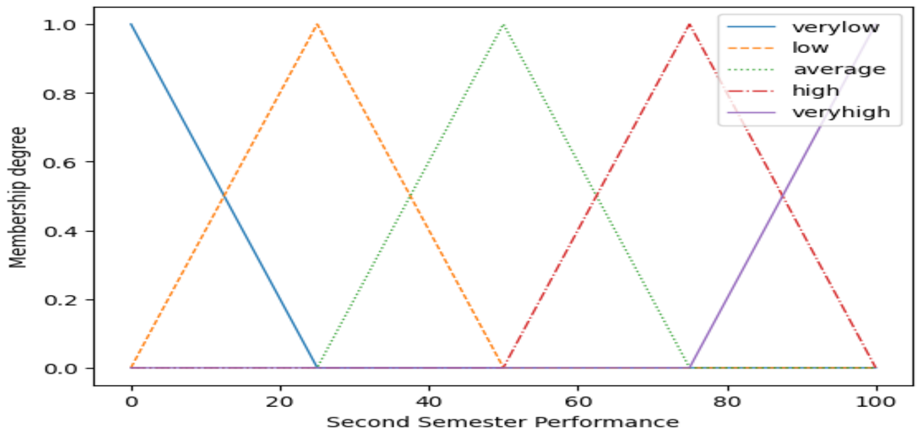


**Figure 4:** Membership function for semester-2 in Fuzzy-1 Method

(Source: Self-Created in Google Colab)

Membership Function for output performance in Fuzzy-1 Method:

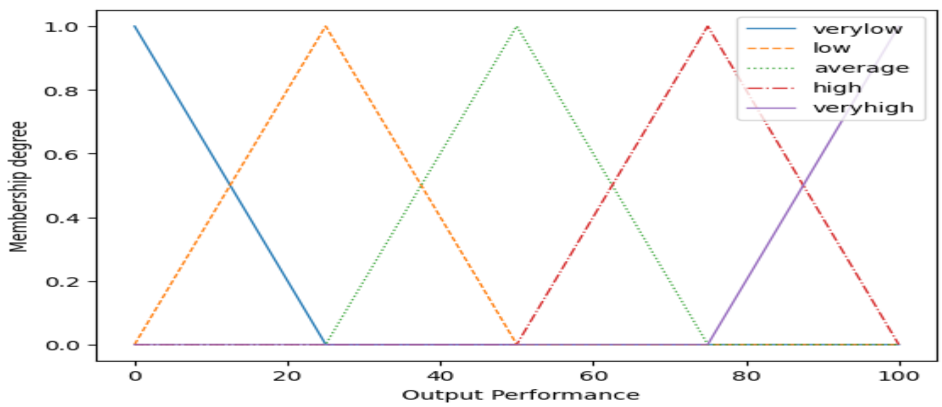


**Figure 5:** Membership function for output performance in Fuzzy-1 Method.

(Source: Self-Created in Google Colab)

Rules and Inference Generation in Fuzzy-1 Method:

The "IF-THEN" rule statements were used to formulate all the rules. There are 25 rules defined. Here the AND operator is used to establish the rules.

```
R1 = "IF (Fsp IS verylow) AND (Ssp IS verylow) THEN (Op IS verylow)"
R2 = "IF (Fsp IS verylow) AND (Ssp IS low) THEN (Op IS verylow)"
R3 = "IF (Fsp IS verylow) AND (Ssp IS average) THEN (Op IS low)"
R4 = "IF (Fsp IS verylow) AND (Ssp IS high) THEN (Op IS low)"
R5 = "IF (Fsp IS verylow) AND (Ssp IS veryhigh) THEN (Op IS average)"
R6 = "IF (Fsp IS low) AND (Ssp IS verylow) THEN (Op IS verylow)"
R7 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS low) AND (Ssp IS average) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS average)"
R10 = "IF (Fsp IS low) AND (Ssp IS veryhigh) THEN (Op IS average)"
R11 = "IF (Fsp IS average) AND (Ssp IS verylow) THEN (Op IS low)"
R12 = "IF (Fsp IS average) AND (Ssp IS low) THEN (Op IS low)"
R13 = "IF (Fsp IS average) AND (Ssp IS average) THEN (Op IS average)"
R14 = "IF (Fsp IS average) AND (Ssp IS high) THEN (Op IS high)"
R15 = "IF (Fsp IS average) AND (Ssp IS veryhigh) THEN (Op IS high)"
R16 = "IF (Fsp IS high) AND (Ssp IS verylow) THEN (Op IS low)"
R17 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS average)"
R18 = "IF (Fsp IS high) AND (Ssp IS average) THEN (Op IS high)"
R19 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R20 = "IF (Fsp IS high) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
R21 = "IF (Fsp IS veryhigh) AND (Ssp IS verylow) THEN (Op IS average)"
R22 = "IF (Fsp IS veryhigh) AND (Ssp IS low) THEN (Op IS high)"
R23 = "IF (Fsp IS veryhigh) AND (Ssp IS average) THEN (Op IS high)"
R24 = "IF (Fsp IS veryhigh) AND (Ssp IS high) THEN (Op IS veryhigh)"
R25 = "IF (Fsp IS veryhigh) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
```

**Figure 6:** "IF-THEN" rules in Google Colab in Fuzzy-1 method.

**Table 5:** Output performance value obtained by Fuzzy-1 Method

| Serial No. | Sem-1 | Sem-2 | Fuzzy-1 |
| --- | --- | --- | --- |
| 1. | 40 | 65 | 53.04 |
| 2. | 20 | 35 | 24.44 |
| 3. | 50 | 65 | 64.51 |
| 4. | 10 | 20 | 20.57 |
| 5. | 45 | 65 | 57.63 |
| 6. | 34 | 60 | 46.17 |
| 7. | 48 | 55 | 53.29 |
| 8. | 56 | 90 | 75.77 |
| 9. | 74 | 70 | 73.51 |
| 10. | 45 | 50 | 47.28 |
| 11. | 65 | 45 | 57.63 |
| 12. | 89 | 100 | 90.57 |
| 13. | 100 | 100 | 91.69 |
| 14. | 65 | 35 | 50 |
| 15. | 48 | 50 | 47.28 |
| 16. | 45 | 55 | 50 |
| 17. | 55 | 25 | 31.03 |
| 18. | 84 | 80 | 76.54 |
| 19. | 63 | 65 | 63.88 |
| 20. | 28 | 30 | 29 |
| 21. | 65 | 40 | 53.04 |
| 22. | 35 | 20 | 24.44 |
| 23. | 65 | 50 | 64.51 |
| 24. | 20 | 10 | 20.57 |
| 25. | 65 | 45 | 57.63 |
| 26. | 60 | 34 | 46.17 |
| 27. | 55 | 48 | 53.29 |
| 28. | 90 | 56 | 75.77 |

| | | | |
|---|---|---|---|
| 29. | 70 | 74 | 73.51 |
| 30. | 50 | 45 | 43.96 |
| 31. | 45 | 65 | 57.63 |
| 32. | 100 | 89 | 90.57 |
| 33. | 35 | 65 | 50 |
| 34. | 50 | 48 | 47.28 |
| 35. | 55 | 45 | 50 |
| 36. | 25 | 55 | 31.03 |
| 37. | 80 | 84 | 76.54 |
| 38. | 65 | 63 | 63.88 |
| 39. | 30 | 28 | 29 |
| 40. | 50 | 39 | 39.51 |
| 41. | 70 | 66 | 68.46 |

### 5.1.1.2 Implementation of Fuzzy-2 Method

Fuzzy Inference System used for the Implementation:

Mamdani type Fuzzy Inference System.

Membership Function used:

Triangular membership function.

**Table 6:** Fuzzy set of input variable for semester-1 in Fuzzy-2 Method

| **Linguistic Variable** | **Interval** |
|---|---|
| verylow | (0,0,25) |
| low | (0,25,50) |
| medium | (25,50,75) |
| high | (50,75,100) |
| veryhigh | (75,100,100) |

**Table 7:** Fuzzy set of input variable for semester-2 in Fuzzy-2 Method

| Linguistic Variable | Interval |
|---|---|
| verylow | (0,0,40) |
| low | (0,20,50) |
| medium | (40,50,60) |
| high | (50,80,100) |
| veryhigh | (60,100,100) |

**Table 8:** Fuzzy set of output variable for performance value in Fuzzy-2 Method

| Linguistic Variable | Interval |
|---|---|
| verylow | (0,0,25) |
| low | (0,25,50) |
| average | (25,50,75) |
| high | (50,75,100) |
| veryhigh | (75,100,100) |

Membership function for semester-1 in Fuzzy-2 Method:

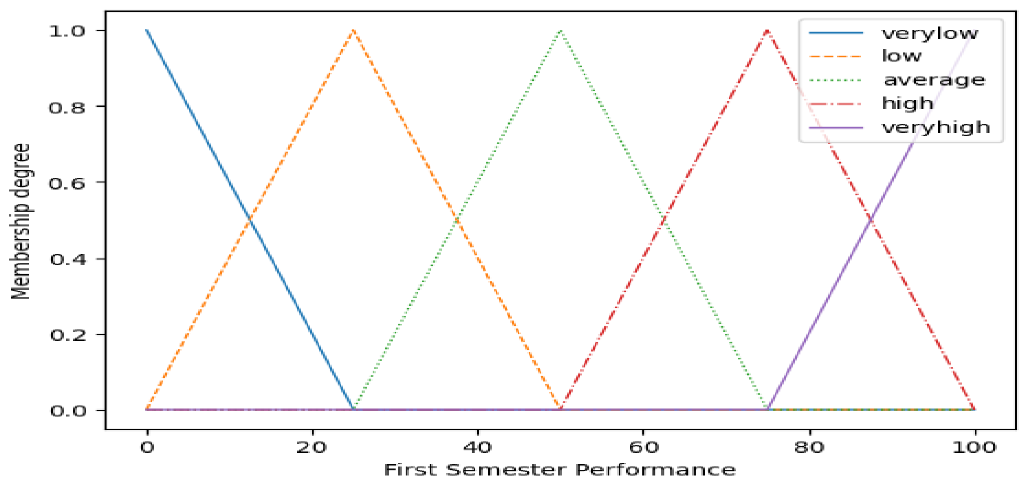


**Figure 7:** Membership function for semester-1 in Fuzzy-2 Method.

(Source: Self-Created in Google Colab)

Membership function for semester-2 in Fuzzy-2 Method:

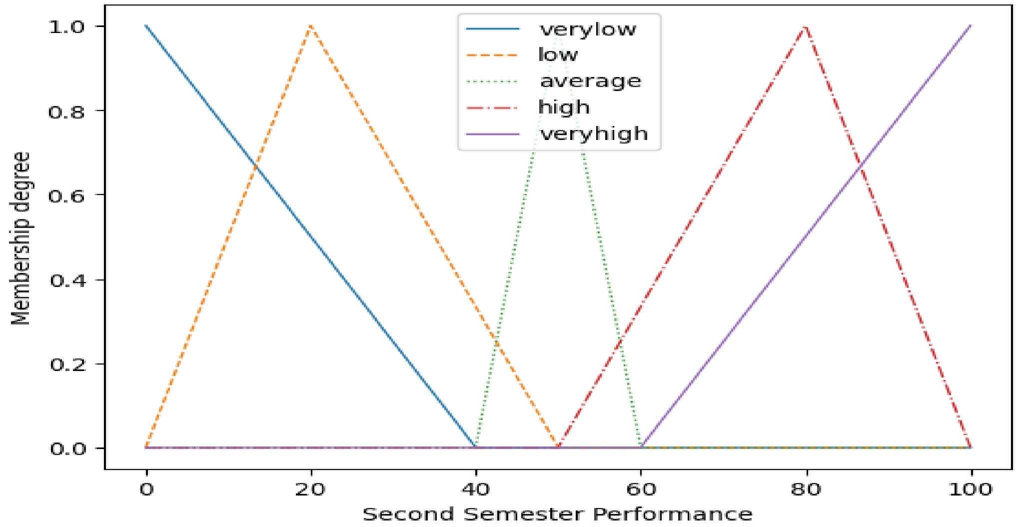


**Figure 8:** Membership function for semester-2 in Fuzzy-2 Method.

(Source: Self-Created in Google Colab)

Membership  Function for output performance in Fuzzy-2 Method:

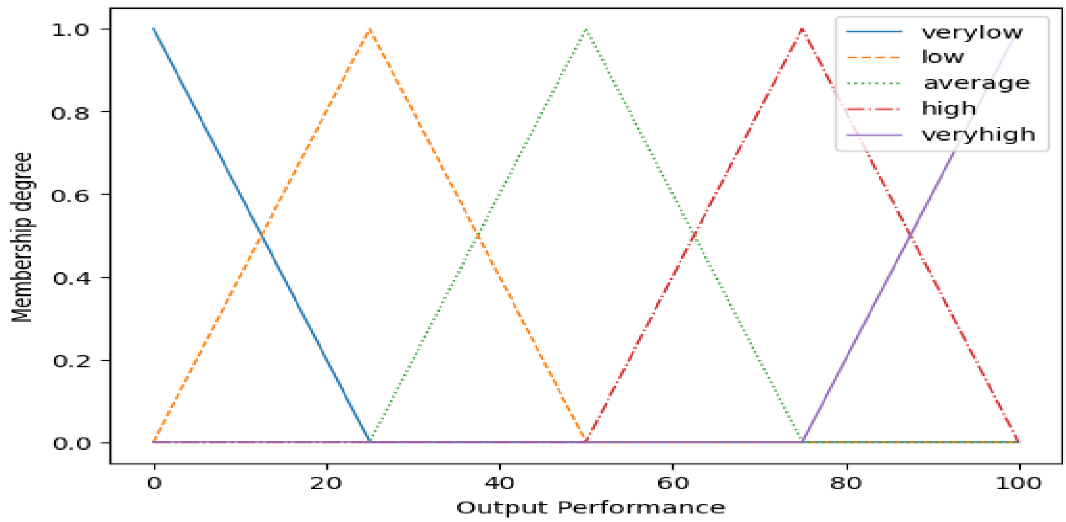


**Figure 9:** Membership function for output performance in Fuzzy-2 Method.

(Source: Self-Created in Google Colab)

Rules and Inference Generation:

The “TF-THEN” rule statements were used to formulate all the rules . There are 25 rules defined. Here the AND operator is used to establish the rules.

R1 = "IF (Fsp IS verylow) AND (Ssp IS verylow) THEN (Op IS verylow)"
R2 = "IF (Fsp IS verylow) AND (Ssp IS low) THEN (Op IS verylow)"
R3 = "IF (Fsp IS verylow) AND (Ssp IS average) THEN (Op IS low)"
R4 = "IF (Fsp IS verylow) AND (Ssp IS high) THEN (Op IS low)"
R5 = "IF (Fsp IS verylow) AND (Ssp IS veryhigh) THEN (Op IS average)"
R6 = "IF (Fsp IS low) AND (Ssp IS verylow) THEN (Op IS verylow)"
R7 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS low) AND (Ssp IS average) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS average)"
R10 = "IF (Fsp IS low) AND (Ssp IS veryhigh) THEN (Op IS average)"
R11 = "IF (Fsp IS average) AND (Ssp IS verylow) THEN (Op IS low)"
R12 = "IF (Fsp IS average) AND (Ssp IS low) THEN (Op IS low)"
R13 = "IF (Fsp IS average) AND (Ssp IS average) THEN (Op IS average)"
R14 = "IF (Fsp IS average) AND (Ssp IS high) THEN (Op IS high)"
R15 = "IF (Fsp IS average) AND (Ssp IS veryhigh) THEN (Op IS high)"
R16 = "IF (Fsp IS high) AND (Ssp IS verylow) THEN (Op IS low)"
R17 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS average)"
R18 = "IF (Fsp IS high) AND (Ssp IS average) THEN (Op IS high)"
R19 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R20 = "IF (Fsp IS high) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
R21 = "IF (Fsp IS veryhigh) AND (Ssp IS verylow) THEN (Op IS average)"
R22 = "IF (Fsp IS veryhigh) AND (Ssp IS low) THEN (Op IS high)"
R23 = "IF (Fsp IS veryhigh) AND (Ssp IS average) THEN (Op IS high)"
R24 = "IF (Fsp IS veryhigh) AND (Ssp IS high) THEN (Op IS veryhigh)"
R25 = "IF (Fsp IS veryhigh) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"

**Figure 10: “**IF-THEN” rules in Google Colab in Fuzzy-2 Method.

**Table 9 :** Output performance value obtained by Fuzzy-2 Method

| Serial No. | Sem-1 | Sem-2 | Fuzzy-2 |
|---|---|---|---|
| 1. | 40 | 65 | 63.69 |
| 2. | 20 | 35 | 24.38 |
| 3. | 50 | 65 | 74.99 |
| 4. | 10 | 20 | 20.57 |
| 5. | 45 | 65 | 67.63 |
| 6. | 34 | 60 | 62.49 |
| 7. | 48 | 55 | 53 |
| 8. | 56 | 90 | 75.69 |
| 9. | 74 | 70 | 75.79 |
| 10. | 45 | 50 | 43.96 |
| 11. | 65 | 45 | 57.47 |
| 12. | 89 | 100 | 90.58 |
| 13. | 100 | 100 | 91.69 |
| 14. | 65 | 35 | 38.69 |
| 15. | 48 | 50 | 47.28 |
| 16. | 45 | 55 | 49.01 |
| 17. | 55 | 25 | 31.03 |
| 18. | 84 | 80 | 77.63 |
| 19. | 63 | 65 | 75.25 |
| 20. | 28 | 30 | 24.20 |
| 21. | 65 | 40 | 37.50 |
| 22. | 35 | 20 | 22.27 |
| 23. | 65 | 50 | 64.51 |
| 24. | 20 | 10 | 20.33 |
| 25. | 65 | 45 | 57.47 |
| 26. | 60 | 34 | 35.99 |
| 27. | 55 | 48 | 53.71 |
| 28. | 90 | 56 | 75.72 |

| | | | |
|---|---|---|---|
| 29. | 70 | 74 | 76.34 |
| 30. | 50 | 45 | 43.56 |
| 31. | 45 | 65 | 67.63 |
| 32. | 100 | 89 | 91.20 |
| 33. | 35 | 65 | 61.30 |
| 34. | 50 | 48 | 47.61 |
| 35. | 55 | 45 | 50.98 |
| 36. | 25 | 55 | 31.43 |
| 37. | 80 | 84 | 78.09 |
| 38. | 65 | 63 | 75.10 |
| 39. | 30 | 28 | 23.94 |
| 40. | 50 | 39 | 25 |
| 41. | 70 | 66 | 75.34 |

## 5.2 Existing Method

Yadav, Soni and Pal proposed a new fuzzy expert system for students' academic performance evaluation based on fuzzy logic techniques.

### 5.2.1 Implementation of Existing Method

**Table 10:** Fuzzy set of input variable for semester-1 in Existing Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

**Table 11:** Fuzzy set of input variable for semester-2 in the Existing Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

**Table 12:** Fuzzy set of output variable for performance value in the Existing Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

Membership function for semester-1 in the Existing Method :

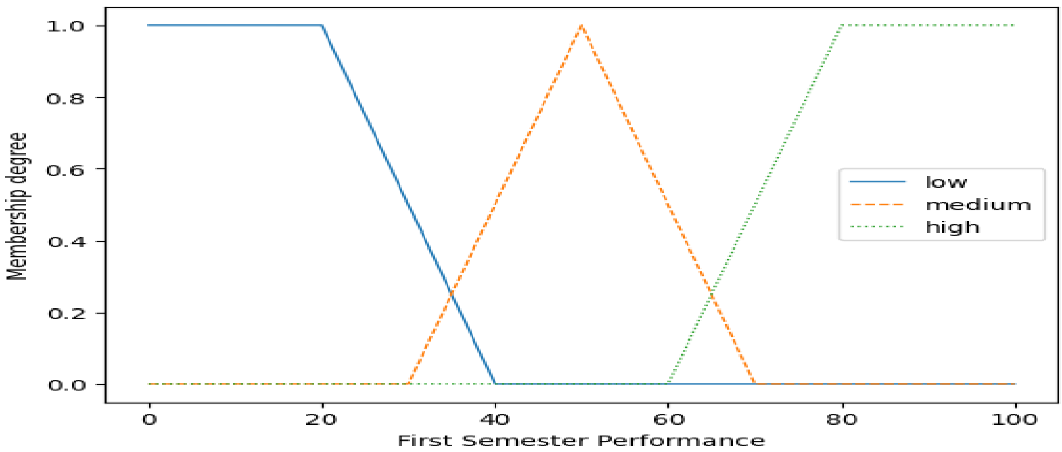


**Figure 11:** Membership function for semester-1 in the Existing Method.

(Source: Self-Created in Google Colab)

Membership function for semester-2 in the Existing Method:

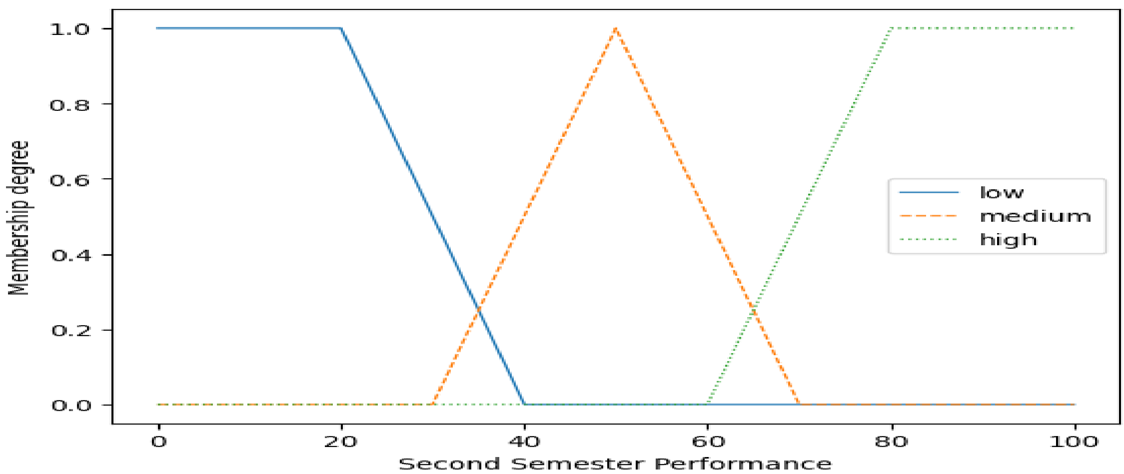


**Figure 12:** Membership function for semester-2 in the Existing Method.

(Source: Self-Created in Google Colab)

Membership Function for output performance in the Existing Method:

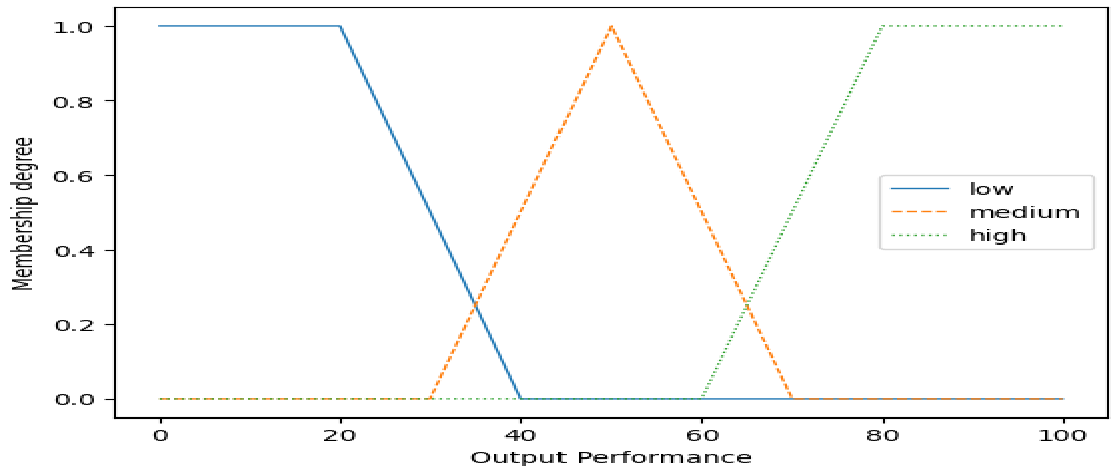


**Figure 13:** Membership function for output performance in the Existing Method.

(Source: Self-Created in Google Colab)

Rules and Inference Generation:

The "IF-THEN" rule statements were used to formulate all the rules . There are 9 rules defined. Here the AND operator is used to establish the rules.

R1 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R2 = "IF (Fsp IS high) AND (Ssp IS medium) THEN (Op IS medium)"
R3 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS medium)"
R4 = "IF (Fsp IS medium) AND (Ssp IS high) THEN (Op IS high)"
R5 = "IF (Fsp IS medium) AND (Ssp IS medium) THEN (Op IS medium)"
R6 = "IF (Fsp IS medium) AND (Ssp IS low) THEN (Op IS low)"
R7 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS medium)"
R8 = "IF (Fsp IS low) AND (Ssp IS medium) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"

**Figure 14:** "IF-THEN" rules in Google Colab in the Existing Method.

**Table 13 :** Output performance value obtained by the Existing Method

| Serial No. | Sem-1 | Sem-2 | Existing Method |
|---|---|---|---|
| 1. | 40 | 65 | 66.25 |
| 2. | 20 | 35 | 18.75 |
| 3. | 50 | 65 | 66.25 |
| 4. | 10 | 20 | 15.52 |
| 5. | 45 | 65 | 66.25 |
| 6. | 34 | 60 | 30.60 |
| 7. | 48 | 55 | 50 |
| 8. | 56 | 90 | 83.27 |
| 9. | 74 | 70 | 82.4 |
| 10. | 45 | 50 | 50 |
| 11. | 65 | 45 | 50 |
| 12. | 89 | 100 | 84.47 |
| 13. | 100 | 100 | 84.47 |
| 14. | 65 | 35 | 33.74 |
| 15. | 48 | 50 | 50 |
| 16. | 45 | 55 | 50 |
| 17. | 55 | 25 | 16.51 |
| 18. | 84 | 80 | 84.47 |
| 19. | 63 | 65 | 66.25 |
| 20. | 28 | 30 | 17.59 |
| 21. | 65 | 40 | 50 |
| 22. | 35 | 20 | 18.75 |
| 23. | 65 | 50 | 50 |
| 24. | 20 | 10 | 15.52 |
| 25. | 65 | 45 | 50 |
| 26. | 60 | 34 | 30.60 |
| 27. | 55 | 48 | 50 |

| | | | |
|---|---|---|---|
| 28. | 90 | 56 | 50 |
| 29. | 70 | 74 | 82.40 |
| 30. | 50 | 45 | 50 |
| 31. | 45 | 65 | 66.25 |
| 32. | 100 | 89 | 84.47 |
| 33. | 35 | 65 | 50 |
| 34. | 50 | 48 | 50 |
| 35. | 55 | 45 | 50 |
| 36. | 25 | 55 | 16.51 |
| 37. | 80 | 84 | 84.47 |
| 38. | 65 | 63 | 62.02 |
| 39. | 30 | 28 | 17.59 |
| 40. | 50 | 39 | 50 |
| 41. | 70 | 66 | 69.39 |

## 5.3 Proposed Modified Method

The fuzzy expert system in the existing research work is modified by changing the "IF-THEN" rules.

### 5.3.1 Implementation of the Proposed Modified Method

**Table 14 :** Fuzzy set of input variable for semester-1 in the Proposed Modified Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

**Table 15 :** Fuzzy set of input variable for semester-2 in the Proposed Modified Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

**Table 16 :** Fuzzy set of output variable for performance value in the Proposed Modified Method

| Linguistic Variable | Interval |
|---|---|
| low | (0,0,20,40) |
| medium | (30,50,70) |
| high | (60,80,100,100) |

Membership function for semester-1 in the Proposed Modified Method:

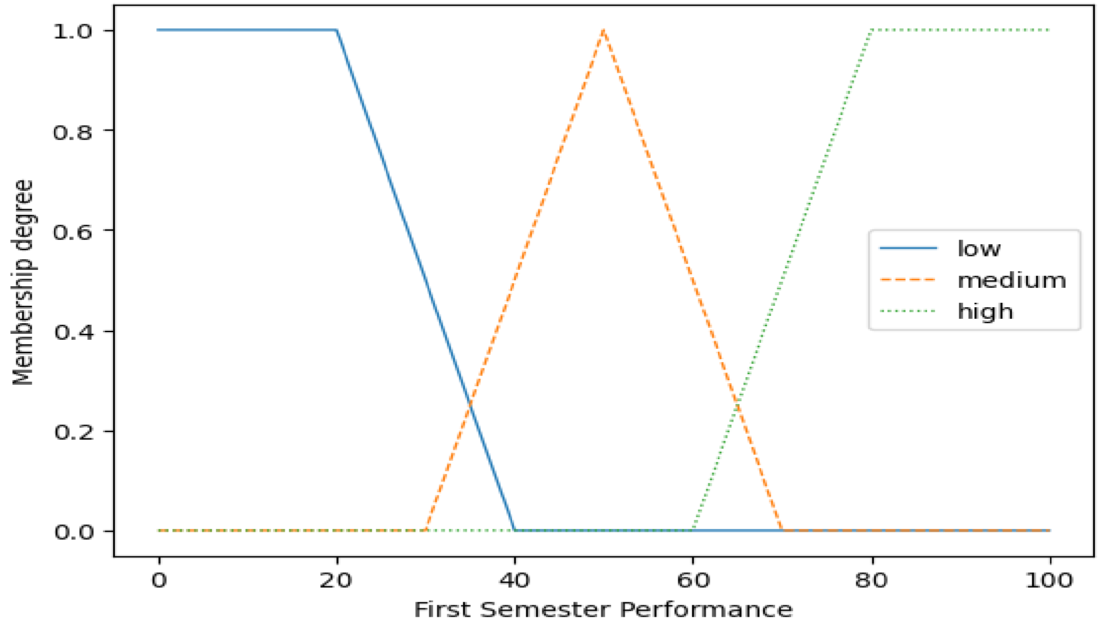


**Figure 15:** Membership function for semester-1 in the Proposed Modified Method.

(Source: Self-Created in Google Colab)

Membership function for semester-2 in the Proposed Modified Method:

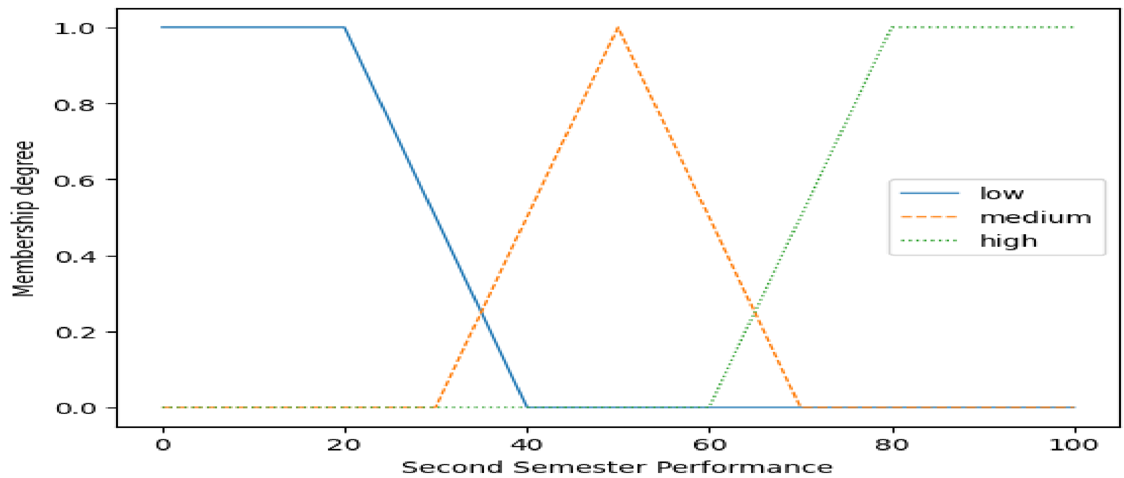


**Figure 16:** Membership function for semester-2 in the Proposed Modified Method.

(Source: Self-Created in Google Colab)

Membership Function for output performance in the Proposed Modified Method :

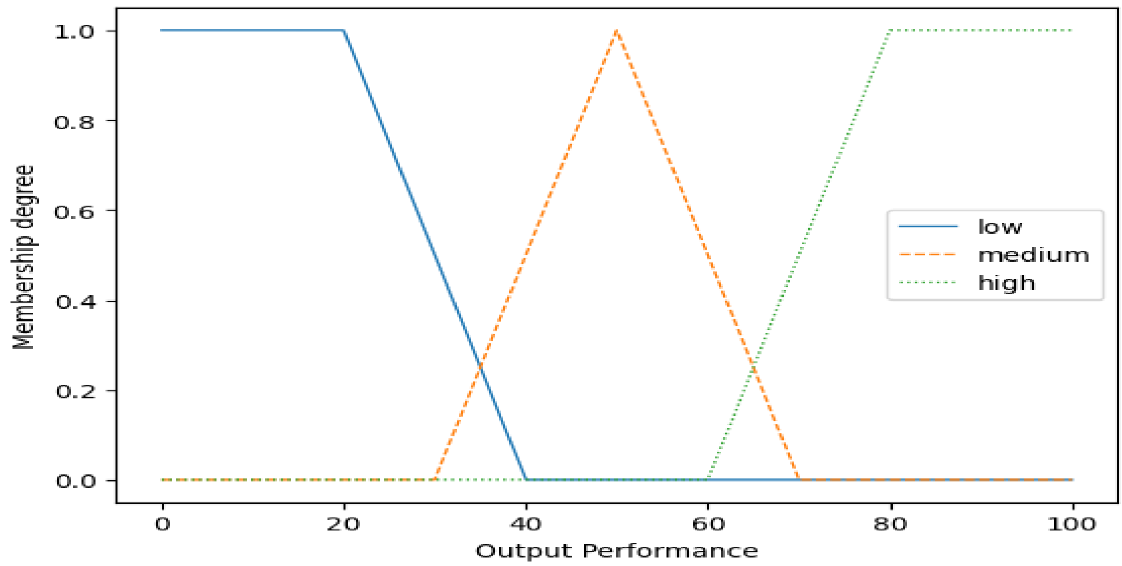


**Figure 17:** Membership function for output performance in the Proposed Modified Method.

(Source: Self-Created in Google Colab)

Rules and Inference Generation:

The “IF-THEN” rule statements were used to formulate all the rules . There are 9 rules defined. Here the AND operator is used to establish the rules.

R1 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R2 = "IF (Fsp IS low) AND (Ssp IS medium) THEN (Op IS medium)"
R3 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS high)"
R4 = "IF (Fsp IS medium) AND (Ssp IS low) THEN (Op IS low)"
R5 = "IF (Fsp IS medium) AND (Ssp IS medium) THEN (Op IS medium)"
R6 = "IF (Fsp IS medium) AND (Ssp IS high) THEN (Op IS high)"
R7 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS high) AND (Ssp IS medium) THEN (Op IS medium)"
R9 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"

**Figure 18:** “IF-THEN” rules in Google Colab in the Proposed Modified Method.

**Table 17 :** Output performance value in the Proposed Modified Method

| Serial No. | Sem-1 | Sem-2 | Proposed Modified Method |
|---|---|---|---|
| 1. | 40 | 65 | 66.25 |
| 2. | 20 | 35 | 33.74 |
| 3. | 50 | 65 | 66.25 |
| 4. | 10 | 20 | 15.52 |
| 5. | 45 | 65 | 66.25 |
| 6. | 34 | 60 | 50 |
| 7. | 48 | 55 | 50 |
| 8. | 56 | 90 | 83.27 |
| 9. | 74 | 70 | 82.4 |
| 10. | 45 | 50 | 50 |
| 11. | 65 | 45 | 50 |
| 12. | 89 | 100 | 84.47 |
| 13. | 100 | 100 | 84.47 |
| 14. | 65 | 35 | 33.74 |
| 15. | 48 | 50 | 50 |
| 16. | 45 | 55 | 50 |
| 17. | 55 | 25 | 16.51 |
| 18. | 84 | 80 | 84.47 |
| 19. | 63 | 65 | 66.25 |
| 20. | 28 | 30 | 17.59 |
| 21. | 65 | 40 | 50 |
| 22. | 35 | 20 | 18.75 |
| 23. | 65 | 50 | 50 |
| 24. | 20 | 10 | 15.52 |
| 25. | 65 | 45 | 50 |

| | | | |
|---|---|---|---|
| 26. | 60 | 34 | 30.60 |
| 27. | 55 | 48 | 50 |
| 28. | 90 | 56 | 50 |
| 29. | 70 | 74 | 82.40 |
| 30. | 50 | 45 | 50 |
| 31. | 45 | 65 | 66.25 |
| 32. | 100 | 89 | 84.47 |
| 33. | 35 | 65 | 66.25 |
| 34. | 50 | 48 | 50 |
| 35. | 55 | 45 | 50 |
| 36. | 25 | 55 | 50 |
| 37. | 80 | 84 | 84.47 |
| 38. | 65 | 63 | 62.02 |
| 39. | 30 | 28 | 17.59 |
| 40. | 50 | 39 | 50 |
| 41. | 70 | 66 | 69.39 |

# Chapter 6

## 6. Comparative Analysis of Classical Average Method, Yadav Singh Method , Existing Method and the Proposed Modified Method.

The aim of this research work is to reward the students who are improving in their study and penalize the students who are deteriorating in their study.

50 is the minimum mark to qualify for the exam.

74.99 is considered as 75, 35.99 as 36 and 49.99 is considered as 50.

**Table 18:** Comparison of the Classical Average Method, the Yadav and Singh Method, the Existing Method and the Proposed Modified Method.

| | | | | Yadav and Singh Method | | | |
|---|---|---|---|---|---|---|---|
| **Serial No.** | **Sem-1** | **Sem-2** | **Classical Average Method** | **Fuzzy-1** | **Fuzzy-2** | **Existing Method** | **Proposed Modified Method** |
| 1. | 40 | 65 | 52.5 | 53.04 | 63.69 | 66.25 | 66.25 |
| 2. | 20 | 35 | 27.5 | 24.44 | 24.38 | 18.75 | 33.74 |
| 3. | 50 | 65 | 57.5 | 64.51 | 75 | 66.25 | 66.25 |
| 4. | 10 | 20 | 15 | 20.57 | 20.57 | 15.52 | 15.52 |
| 5. | 45 | 65 | 55 | 57.63 | 67.63 | 66.25 | 66.25 |
| 6. | 34 | 60 | 47 | 46.17 | 62.49 | 50 | 50 |
| 7. | 48 | 55 | 51.5 | 53.29 | 53 | 50 | 50 |
| 8. | 56 | 90 | 73 | 75.77 | 75.69 | 83.27 | 83.27 |
| 9. | 74 | 70 | 72 | 73.51 | 75.79 | 82.4 | 82.4 |
| 10. | 45 | 50 | 47.5 | 47.28 | 43.96 | 50 | 50 |
| 11. | 65 | 45 | 55 | 57.63 | 57.47 | 50 | 50 |
| 12. | 89 | 100 | 100 | 90.57 | 90.58 | 84.47 | 84.47 |
| 13. | 100 | 100 | 100 | 91.69 | 91.69 | 84.47 | 84.47 |
| 14. | 65 | 35 | 50 | 50 | 38.69 | 33.74 | 33.74 |
| 15. | 48 | 50 | 49 | 47.28 | 47.28 | 50 | 50 |
| 16. | 45 | 55 | 50 | 50 | 49.01 | 50 | 50 |
| 17. | 55 | 25 | 40 | 31.03 | 31.03 | 16.51 | 16.51 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18. | 84 | 80 | 82 | 76.54 | 77.63 | 84.47 | 84.47 |
| 19. | 63 | 65 | 64 | 63.88 | 75.25 | 66.25 | 66.25 |
| 20. | 28 | 30 | 29 | 29 | 24.20 | 17.59 | 17.59 |
| 21. | 65 | 40 | 52.5 | 53.04 | 37.50 | 50 | 50 |
| 22. | 35 | 20 | 27.5 | 24.44 | 22.27 | 18.75 | 18.75 |
| 23. | 65 | 50 | 57.5 | 64.51 | 64.51 | 50 | 50 |
| 24. | 20 | 10 | 15 | 20.57 | 20.33 | 15.52 | 15.52 |
| 25. | 65 | 45 | 55 | 57.63 | 57.47 | 50 | 50 |
| 26. | 60 | 34 | 47 | 46.17 | 36 | 30.60 | 30.60 |
| 27. | 55 | 48 | 51.5 | 53.29 | 53.71 | 50 | 50 |
| 28. | 90 | 56 | 73 | 75.77 | 75.72 | 50 | 50 |
| 29. | 70 | 74 | 72 | 73.51 | 76.34 | 82.40 | 82.40 |
| 30. | 50 | 45 | 47.5 | 43.96 | 43.56 | 50 | 50 |
| 31. | 45 | 65 | 55 | 57.63 | 67.63 | 66.25 | 66.25 |
| 32. | 100 | 89 | 94.5 | 90.57 | 91.20 | 84.47 | 84.47 |
| 33. | 35 | 65 | 50 | 50 | 61.30 | 50 | 66.25 |
| 34. | 50 | 48 | 49 | 47.28 | 47.61 | 50 | 50 |
| 35. | 55 | 45 | 50 | 50 | 50.98 | 50 | 50 |
| 36. | 25 | 55 | 40 | 31.03 | 31.43 | 16.51 | 50 |
| 37. | 80 | 84 | 82 | 76.54 | 78.09 | 84.47 | 84.47 |
| 38. | 65 | 63 | 64 | 63.88 | 75.10 | 62.02 | 62.02 |
| 39. | 30 | 28 | 29 | 29 | 23.94 | 17.59 | 17.59 |
| 40. | 50 | 39 | 44.5 | 39.51 | 25 | 50 | 50 |
| 41. | 70 | 66 | 68 | 68.46 | 75.34 | 69.39 | 69.39 |

1) If a student scores less than 50 in both the semesters then he/she is unable to qualify in Classical, Fuzzy-1, Fuzzy-2, Existing and the Proposed Modified Method. This statement is proved in the following rows: row2,row4, row20, row22, row24, row39.

2) If a student scores 50 or more than 50 in both the semesters then he/she is able to qualify in Classical, Fuzzy-1, Fuzzy-2, Existing and the Proposed Modified Method. This statement is proved in the following rows: row3, row8, row9, row12, row13, row18, row19, row 23, row28, row29, row32, row37,row38, row41.

3) If the scores of sem-1 and sem-2 are swapped then the score obtained in the Fuzzy-1 Method before and after swapping remains the same. For example, in row 1, sem-1 score is 40 and sem-2 score is 65 and in row21, sem-1 score is 65 and sem-2 score is 40 , in both the cases the result is 53.04 in Fuzzy-1 Method. That is the Fuzzy-1 Method is unable to reward or penalize the students. So, the Fuzzy-1 Method is not discussed further in this comparative analysis.

4) In row1 where the sem-2 score is greater than the sem-1 score, the score in the Fuzzy-2 Method is more than the Classical Average Method and improved in the Existing Method and the Proposed Modified Method.

5) In row2 where the sem-2 score is greater than the sem-1 score, the score in the Fuzzy-2 Method is more than the Classical Method and improved in the Proposed Modified Method. But in the Existing Method the score is decreased which penalizes the student for improvement in study. But the student performance is not influenced by this result because the sem-1 marks is 20 and sem-2 marks is 35 which are not pass marks in both the semesters.

6) In row3 where the sem-2 score is greater than the sem-1 score, the score in the Existing Method and the Proposed Modified Method is more than the Classical Average Method and improved in the Fuzzy-2 Method.

7) In row4 where the sem-2 score is greater than the sem-1 score, the score in the Existing Method and the Proposed Modified Method is more than the Classical Average Method and improved in the Fuzzy-2 Method.

8) In row5 where the sem-2 score is greater than the sem-1 score, the scores in the Existing Method and the Proposed Modified Method are more than the Classical Average Method and improved in the Fuzzy-2 Method.

9) In row6 where the sem-2 score is greater than the sem-1 score, the student scored more in the Proposed Modified Method and the Existing Method than the Classical Average Method and improved in the Fuzzy-2 Method.

10) In row7 where the sem-2 score is greater than the sem-1 score, the scores in the Existing Method and the Proposed Modified Method are almost the same or little less than the Classical Average Method as they are average marks but improved in the Fuzzy-2 Method.

11) In row8 where the sem-2 score is greater than the sem-1 score, the score in the Fuzzy-2 Method is more than the Classical Average Method and improved in the Existing Method and the Proposed Modified Method.

12) If a student scores 70 or more than 70 but less than 80 in both of the semesters then a fixed value 82.4 is obtained for the Existing Method and the Proposed Modified Method. The fixed marks obtained in the Existing Method and the Proposed Modified Method is more than the Classical Average Method and the Fuzzy-2 Method. It is found that there is a pattern obtained in the Existing Method and the Proposed Modified Method that a student who obtained 70 or more than 70 but less than 80 in both the semesters is rewarded by a fixed mark of 82.4. The fixed marks obtained in the Existing method and the Proposed Modified Method is more than the Classical Average Method and the Fuzzy-2 Method. So, the Existing Method and the Proposed Modified Method can reward the students who score 70 or more than 70 but less than 80 both semesters. The result is proved in the following rows: row9, row29.

13) In row10 where sem-2 score is greater than sem-1 score, the scores in the Existing Method and the Proposed Modified Method is more than the Classical Average Method but decreased in the Fuzzy-2 Method, that is the student is penalized for improving in study in the Fuzzy-2 Method.

14) In row11 where the sem-1 score is greater than the sem-2 score, the scores in the Existing Method and the Proposed Modified Method are less than the Classical Average Method but increased in the Fuzzy-2 Method, that is the student is rewarded for deterioration in study in the Fuzzy-2 Method.

15) If a student scores 80 or more than 80 in both of the semesters then a fixed value 84.47 is obtained for the Existing Method and the Proposed Modified Method. The statement is proved in the following rows: row12, row13, row18, row32, row37.

16) In row12, a student scored 89 in sem-1 and 100 in sem-2 and the student's score is not increased in the Fuzzy-2 method, the Existing Method and the Proposed Modified Method and the fixed value 84.7 is obtained in the Existing Method and Proposed Modified Method. This is the limitation of the Fuzzy-2 Method, the Existing Method and the Proposed Modified Method in comparison with the Classical Average Method.

17) In row13 a student gets 100 in both the semester examinations and the student's score is not 100 in the Fuzzy-2 Method, Existing Method and the Proposed Modified Method. This is another limitation of the Fuzzy-2 Method, the Existing Method and the Proposed Modified Method in comparison with the Classical Average Method.

18) In row14 where the sem-1 score is greater than sem-2 score, the student's score is decreased in the Fuzzy-2 Method than the Classical Average Technique and the score more decreased in the Existing Method and the Proposed Modified Method.

19) In row15 where the sem-2 score is greater than the sem-1 score, the student disqualified in the classical method but qualified in the Existing Method and the Proposed Modified Method but the student's score is decreased in the Fuzzy-2 Method than the Classical Average Method, the Existing Method and the Proposed Modified Method and the student also disqualified in the Fuzzy-2 Method that is the student is penalized for improving in study in the Fuzzy-2 Method.

20) In row16 where the sem-2 score is greater than sem-1 score, the student qualified in the classical, the Existing Method and the Proposed Modified Method. But disqualified in the Fuzzy-2 Method that is the student penalized for improving in study in the Fuzzy-2 Method.

21) In row17 where the sem-1 score is greater than sem-2 score, the score in the Fuzzy-2 Method is less than the Classical Average Method and more decreased in the Existing Method and the Proposed Modified Method.

22) In row19 where the sem-2 score is greater than the sem-1 score, the student score increased in the Existing Method and the Proposed Modified Method and improved in the Fuzzy-2 Method.

23) In row20 where the sem-2 score is greater than the sem-1 score, the student's score is decreased in the Fuzzy-2 Method, Existing Method and the

Proposed Modified Method. But the student performance is not influenced by this result because the sem-1 marks is 28 and sem-2 marks is 30 which are disqualifying marks in both the semesters.

24) In row21 where the sem-1 score is greater than the sem-2 score, the score is decreased in the Existing Method and the Proposed Modified Method and more decreased in the Fuzzy-2 Method.

25) In row22 where the sem-1 score is greater than sem-2 the score is decreased in the Fuzzy-2 Method than the Classical Average Method and more decreased in the Existing Method and the Proposed Modified Method.

26) In row23 where the sem-1 score is greater than the sem-2 score, the score is decreased in the Existing Method and Proposed Modified Method but increased in the Fuzzy-2 Method. That is the student is rewarded for deteriorating in study in Fuzzy-2 Method.

27) In row24 where the sem-1 score is greater than sem-2 the score is decreased in the Existing Method and the Proposed Modified Method but increased in the Fuzzy-2 Method. That is the student is rewarded for deteriorating in study in the Fuzzy-2 Method. But this result is negligible as sem-1 marks is 20 and sem-2 marks is 10 which are marks for disqualifying a student.

28) In row25 where the sem-1 score is greater than the sem-2 score the score is decreased in the Existing Method and the Proposed Modified Method but increased in the Fuzzy-2 Method. That is the student is rewarded for deteriorating in study in the Fuzzy-2 Method.

29) In row26 where the sem-1 score is greater than the sem-2 score, the score is decreased in the Fuzzy-2 method than the Classical Method and more decreased in the Existing Method and the Proposed Modified Method.

30) In row27 where the sem-1 score is greater than the sem-2 the score is decreased in the Existing Method and the Proposed Modified Method but increased in the Fuzzy-2 Method. That is the student is rewarded for deteriorating in study in the Fuzzy-2 Method.

31) In row28 where the sem-1 score is greater than sem-2 score, the score is decreased in the Existing Method and the Proposed Modified Method but increased in the Fuzzy-2 Method than the Classical Average Method. That is the student is rewarded for deteriorating in study in the Fuzzy-2 Method.

32) In row29 where the sem-2 score is greater than sem-1 score, the score is increased in the Fuzzy-2 Method than the Classical Average Method and more in the Existing Method and the Proposed Modified Method.

33) If a student qualified in sem-1 and disqualified in sem-2 then the student is passed in the Existing Method and the Proposed Modified Method when the difference between sem-1 and sem-2 score is 25 or less than 25. The statement is proved in the following rows: row11, row21, row25, row30, row34, row35, row40.

34) In row30 where the sem-1 score is greater than the sem-2 score, the student qualified in the Existing Method and the Proposed Modified Method but the score is decreased in the Fuzzy-2 Method than the Classical Average Technique.

35) In row31 where the sem-2 score is greater than sem-1 score, the score is increased in the Existing Method and the Proposed Modified Method and improved in the Fuzzy-2 Method.

36) In row32 where the sem-1 score is greater than the sem-2 score the score is decreased in the Fuzzy-2 method and more decreased in Existing Method and the Proposed Modified Method.

37) In row33 where the sem-2 score is greater than the sem-1 score , the score is the same as the Classical Method in the Existing method but increased in the Fuzzy-2 Method and more improved in the Proposed Modified Method. That is the student is not rewarded for improvement in studying by the Existing Method.

38) In row36 where the sem-2 score is greater than the sem-1 score the student was disqualified in the Classical Method but qualified in the Proposed Modified Method. But the student's score is decreased in the Fuzzy-2 Method and more decreased in the Existing Method. That is the student is penalized for improving in study in Fuzzy-2 and the Existing Method.

39) In row37 where the sem-2 score is greater than the sem-1 score the student's score in the Existing Method and the Proposed Modified Method is more than the Classical Method. But the student's score is decreased in the Fuzzy-2 method, that is the student is penalized for improving in study in the Fuzzy-2 method.

40) In row38 where the sem-1 score is greater than the sem-2 score, the student's score is decreased in the Existing Method and the Proposed Modified Method but increased in the Fuzzy-2 Method. That is the student is rewarded for deteriorating in study in the Fuzzy-2 Method.

41) In row39 where the sem-2 score is greater than the sem-1 score, the student's score is decreased in the Fuzzy-2 Method and more decreased in the Existing Method and the Proposed Modified Method. But the student performance is not influenced by this result because the sem-1 marks is 30 and sem-2 marks is 28 which are marks for disqualifying a student.

42) In row41 where sem-1 score is 70 and sem-2 score is 66 the student's score is almost the same or little more in the Existing Method and the Proposed Modified Method but more increased in the Fuzzy-2 method. That is the student is not penalized for deteriorating in study in the Existing Method and Proposed Modified method as the difference between sem-1 and sem-2 score is less than 25 but rewarded for deteriorating in study in the Fuzzy-2 Method.

### 6.1 Discussion

Fuzzy-1 Method:

If the scores of sem-1 and sem-2 are swapped then the score obtained in the Fuzzy-1 method remains the same before and after swapping. That is the Fuzzy-1 Method is unable to reward or penalize a student based on their improvement or deterioration in study.

Fuzzy-2 Method:

If a student scores more in sem-2 than sem-1 then there are many cases where Fuzzy-2 scores better than the Classical Average Technique, the Existing Method and the Proposed Modified Method but this result is not obtained for all possible rows in Table 18 and there are many cases where the student is penalized for improvement in study.

If a student scores more in sem-1 than sem-2 then many cases are found where Fuzzy-2 scores less than the Classical Average Technique , Existing Method and the Proposed Modified Method but this result is not obtained for all the possible rows in Table 18 and there are many cases found where the student is rewarded for deterioration in study.

Therefore, it can be concluded that the Fuzzy-2 method is uncertain about a student's academic performance evaluation based on their improvement or deterioration in study.

In row12, a student scored 89 in sem-1 and 100 in sem-2 and the student's score decreased in the Fuzzy-2 Method. In row13 a student gets 100 in both the semester examinations then the student's score is not 100 in the Fuzzy-2 method.

That is, the Fuzzy-2 Method is not working in the case of the highest value 100.

Existing Method:

Existing Method is the earlier version of the Proposed Modified Method but with different rules. There are many cases found where the Existing Method scored better than the Fuzzy-2 Method. The Existing Method gives almost similar results as the Proposed Modified Method but there are some cases found where the Sem-2 score is greater than the Sem-1 score but the Existing Method penalized or not rewarded the student for the improvement in study.

Therefore, there is an uncertainty in the Existing Method for student's academic performance evaluation based on their improvement or deterioration in study.

If a student scores 70 or more than 70 but less than 80 in both of the semesters then a fixed mark of 82.4 is obtained for the Existing Method. The fixed marks obtained in the Existing Method is more than the Classical Average Technique and the Fuzzy-2 Method. It is found that there is a pattern obtained in the Existing Method that a student who obtained 70 or more than 70 but less than 80 in both the semesters is rewarded by a fixed mark of 82.4. So, the Existing method can reward the students who score 70 or more than 70 in but less than 80 in both the semesters. This pattern is not obtained in the Fuzzy-2 Method.

If a student scores 80 or more than 80 in both of the semesters then a fixed value 84.47 is obtained for the Existing Method. But in row12, a student scored 89 in sem-1 and 100 in sem-2 and the student's score is decreased in the Existing Method than the Classical Method and the fixed value 84.7 is obtained in the Existing Method. If a student gets 100 in both the semester examinations then the student's score is not 100 in the Existing Method and a fixed value 84.47 is obtained.

That is, the Existing Method is also not working in case of the highest value 100.

If a student qualifies in sem-1 and is disqualified in sem-2 then the student is qualified in the Existing Method when the difference between sem-1 and sem-2 score is 25 or less than 25. Therefore there is a pattern obtained in the Existing Method for qualifying or disqualifying a student according to the difference of the examination marks which is not obtained in the Fuzzy-2 Method.

Proposed Modified Method:

Proposed Modified Method is the modified version of the Existing Method with modified rules. There are many cases found where the Proposed Modified Method gives scores better than the Fuzzy-2 Method and the Existing Method.

The Proposed Modified Method gives almost similar results as the Existing Method but the limitation of the Existing Method is not in the Proposed Modified Method.

If a student scores 70 or more than 70 but less than 80 in both of the semesters then a fixed value 82.4 is obtained for the Existing Method and the Proposed Modified Method. The fixed marks obtained in the Existing Method and the Proposed Modified Method is more than the Classical Average Technique and the Fuzzy-2 Method. Therefore, there is a pattern obtained in the Proposed Modified Method that a student who obtained 70 or more than 70 but less than 80 in both the semesters is rewarded by a fixed mark of 82.4. This pattern is not obtained in the Fuzzy-2 method.

So, the Proposed Modified Method can reward the students who score 70 or more than 70 but less than 80 in both the semesters.

If a student scores 80 or more than 80 in both of the semesters then a fixed value 84.47 is obtained for the Existing Method and the Proposed Modified Method. This pattern is not obtained in the Fuzzy-2 Method. But in row12, a student scored 89 in sem-1 and 100 in sem-2 and the student's score is decreased compared to the Classical Average Method and the fixed value 84.7 is obtained in the Proposed Modified Method. In row 13 a student gets 100 in both the semester examinations then the student's score is not 100 in the Proposed Modified Method.

Therefore, the Proposed Modified Method is also not working in the case of highest value 100.

If a student qualifies in sem-1 and is disqualified in sem-2 then the student is qualified in the Proposed Modified Method when the difference between sem-1 and sem-2 score is 25 or less than 25. Therefore there is a pattern obtained in the Proposed Modified Method to qualify or disqualify a student based on difference in examination marks which is not obtained in the Fuzzy-2 Method.

# Chapter 7

# 7. Conclusion and Future Scope

## 7.1 Conclusion

In this research work, the differences in results are seen between the Classical Average Method, the Fuzzy-1 Method, the Fuzzy-2 Method, the Existing method and the Proposed Modified Method. In the Fuzzy-1 Method , if the scores of sem-1 and sem-2 are swapped then the score obtained in the Fuzzy-1 Method remains the same before and after swapping. That is the Fuzzy-1 Method is unable to reward or penalize the students based on their improvement or deterioration in study. Fuzzy-2 Method and the Existing Method is found uncertain about student's academic performance evaluation based on their improvement or deterioration in study. The Proposed Modified Method is found more suitable for students' performance evaluation in comparison to the Existing Method as the uncertainty is removed by the modified rules. But fuzzy evaluation methods are not working in case of highest value 100 which is a limitation. It is advised to implement the method in the MATLAB Fuzzy logic toolbox before implementing in python(if possible) for a better understanding of the concepts.

## 7.2 Future Scope

The research work can also be implemented with skfuzzy python library along with numpy instead of simpful. To change the defuzzification method, it is advised to use python libraries like skfuzzy with numpy instead of simpful. Total number of samples present in the database is 41 .This method can be applied for a large data set with more samples. Future researchers can also modify the method by changing membership functions, by adding more or new rules etc. They can also propose their own method.

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# APPENDIX A

**System Requirement : Windows7 or later version**

**Software Requirement: Google Chrome**

# APPENDIX B

## Python codes used for the implementation of Yadav and Singh Method, Existing Method and Proposed Modified Method

### Code used for implementation of Yadav and Singh Method:

### Code used for implementation of Fuzzy-1 Method:

```
#Fuzzy-1 Method
# A Mamdani FIS for the Fuzzy-1 method, defined in Simpful.
! pip install simpful
from simpful import *
# A fuzzy inference system for the Fuzzy-1 method
# Create a fuzzy system object
FS = FuzzySystem()
# Define fuzzy sets and linguistic variables
S_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=25), term="verylow")
S_2 = FuzzySet(function=Triangular_MF(a=0, b=25, c=50), term="low")
S_3 = FuzzySet(function=Triangular_MF(a=25, b=50, c=75), term="average")
S_4 = FuzzySet(function=Triangular_MF(a=50, b=75, c=100), term="high")
S_5 = FuzzySet(function=Triangular_MF(a=75, b=100, c=100), term="veryhigh")
LV1 = LinguisticVariable([S_1,S_2,S_3,S_4,S_5], concept="First Semester Performance", universe_of_discourse=[0,100])
FS.add_linguistic_variable("Fsp", LV1)
LV1.plot()
F_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=25), term="verylow")
F_2 = FuzzySet(function=Triangular_MF(a=0, b=25, c=50), term="low")
F_3 = FuzzySet(function=Triangular_MF(a=25, b=50, c=75), term="average")
F_4 = FuzzySet(function=Triangular_MF(a=50, b=75, c=100), term="high")
F_5 = FuzzySet(function=Triangular_MF(a=75, b=100, c=100), term="veryhigh")
LV2 = LinguisticVariable([F_1,F_2,F_3,F_4,F_5], concept="Second Semester Performance", universe_of_discourse=[0,100])
FS.add_linguistic_variable("Ssp", LV2)
LV2.plot()
# Define output fuzzy sets and linguistic variable
T_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=25), term="verylow")
T_2 = FuzzySet(function=Triangular_MF(a=0, b=25, c=50), term="low")
T_3 = FuzzySet(function=Triangular_MF(a=25, b=50, c=75), term="average")
T_4 = FuzzySet(function=Triangular_MF(a=50, b=75, c=100), term="high")
T_5 = FuzzySet(function=Triangular_MF(a=75, b=100, c=100), term="veryhigh")
```

```
LV3 = LinguisticVariable([T_1,T_2,T_3,T_4,T_5], concept=" Output Performance", universe_of_discourse=[0,100])
FS.add_linguistic_variable("Op", LV3)
LV3.plot()
# Define fuzzy rules
R1 = "IF (Fsp IS verylow) AND (Ssp IS verylow) THEN (Op IS verylow)"
R2 = "IF (Fsp IS verylow) AND (Ssp IS low) THEN (Op IS verylow)"
R3 = "IF (Fsp IS verylow) AND (Ssp IS average) THEN (Op IS low)"
R4 = "IF (Fsp IS verylow) AND (Ssp IS high) THEN (Op IS low)"
R5 = "IF (Fsp IS verylow) AND (Ssp IS veryhigh) THEN (Op IS average)"
R6 = "IF (Fsp IS low) AND (Ssp IS verylow) THEN (Op IS verylow)"
R7 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS low) AND (Ssp IS average) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS average)"
R10 = "IF (Fsp IS low) AND (Ssp IS veryhigh) THEN (Op IS average)"
R11 = "IF (Fsp IS average) AND (Ssp IS verylow) THEN (Op IS low)"
R12 = "IF (Fsp IS average) AND (Ssp IS low) THEN (Op IS low)"
R13 = "IF (Fsp IS average) AND (Ssp IS average) THEN (Op IS average)"
R14 = "IF (Fsp IS average) AND (Ssp IS high) THEN (Op IS high)"
R15 = "IF (Fsp IS average) AND (Ssp IS veryhigh) THEN (Op IS high)"
R16 = "IF (Fsp IS high) AND (Ssp IS verylow) THEN (Op IS low)"
R17 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS average)"
R18 = "IF (Fsp IS high) AND (Ssp IS average) THEN (Op IS high)"
R19 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R20 = "IF (Fsp IS high) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
R21 = "IF (Fsp IS veryhigh) AND (Ssp IS verylow) THEN (Op IS average)"
R22 = "IF (Fsp IS veryhigh) AND (Ssp IS low) THEN (Op IS high)"
R23 = "IF (Fsp IS veryhigh) AND (Ssp IS average) THEN (Op IS high)"
R24 = "IF (Fsp IS veryhigh) AND (Ssp IS high) THEN (Op IS veryhigh)"
R25 = "IF (Fsp IS veryhigh) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
FS.add_rules([R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25])
# Set antecedents values
FS.set_variable("Fsp", 80 )
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 35)
# Perform Mamdani inference and print output
print(FS.Mamdani_inference(["Op"]))
```

```
{'Op': 75.55399299238728}
{'Op': 24.446007007613296}
```

```
FS.set_variable("Fsp", 40)
```

```
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 53.04877437190766}

```
FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 24.446007007613296}

```
FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 64.5160999126996}

```
FS.set_variable("Fsp", 10)
FS.set_variable("Ssp", 20)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 20.57958930183036}

```
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 57.638873565170066}

```
FS.set_variable("Fsp", 34)
FS.set_variable("Ssp", 60)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 46.175007673003506}

```
FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 53.29031598021224}

```
FS.set_variable("Fsp", 56)
FS.set_variable("Ssp", 90)
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 75.77580808316287}

```
FS.set_variable("Fsp", 74)
FS.set_variable("Ssp", 70)
```

```
print(FS.Mamdani_inference(["Op"]))
{'Op': 73.51995281854988}

FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))

{'Op': 47.280184293555315}

FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))

{'Op': 57.638873565170066}

FS.set_variable("Fsp", 89)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))

{'Op': 90.572547678132}

FS.set_variable("Fsp", 100)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))
{'Op': 91.6999834165503}

FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.0000000000007}

FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 47.280184293555315}

FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.000000000000234}

FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 25)
print(FS.Mamdani_inference(["Op"]))

{'Op': 31.03452080371465}

FS.set_variable("Fsp", 84)
```

```
FS.set_variable("Ssp", 80)
print(FS.Mamdani_inference(["Op"]))
{'Op': 76.54244824168113}
```

```
FS.set_variable("Fsp", 63)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))

{'Op': 63.88506106560483}
```

```
FS.set_variable("Fsp", 28)
FS.set_variable("Ssp", 30)
print(FS.Mamdani_inference(["Op"]))

{'Op': 29.00004212629447}
```

## Code used for implementation of Fuzzy-2 Method:

```
#Fuzzy-2 Method
! pip install simpful
#A Mamdani FIS for the Fuzzy-2 method, defined in Simpful.
from simpful import *
# A fuzzy inference system for the Fuzzy-2 Method
# Create a fuzzy system object
FS = FuzzySystem()
# Define fuzzy sets and linguistic variables
S_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=25), term="verylow")
S_2 = FuzzySet(function=Triangular_MF(a=0, b=25, c=50), term="low")
S_3 = FuzzySet(function=Triangular_MF(a=25, b=50, c=75), term="average")
S_4 = FuzzySet(function=Triangular_MF(a=50, b=75, c=100), term="high")
S_5 = FuzzySet(function=Triangular_MF(a=75, b=100, c=100), term="veryhigh")
LV1 = LinguisticVariable([S_1,S_2,S_3,S_4,S_5], concept="First Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Fsp", LV1)
LV1.plot()
F_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=40), term="verylow")
F_2 = FuzzySet(function=Triangular_MF(a=0, b=20, c=50), term="low")
F_3 = FuzzySet(function=Triangular_MF(a=40, b=50, c=60), term="average")
F_4 = FuzzySet(function=Triangular_MF(a=50, b=80, c=100), term="high")
F_5 = FuzzySet(function=Triangular_MF(a=60, b=100, c=100), term="veryhigh")
LV2 = LinguisticVariable([F_1,F_2,F_3,F_4,F_5], concept="Second Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Ssp", LV2)
LV2.plot()
 # Define output fuzzy sets and linguistic variables
T_1 = FuzzySet(function=Triangular_MF(a=0, b=0, c=25), term="verylow")
```

```
T_2 = FuzzySet(function=Triangular_MF(a=0, b=25, c=50), term="low")
T_3 = FuzzySet(function=Triangular_MF(a=25, b=50, c=75), term="average")
T_4 = FuzzySet(function=Triangular_MF(a=50, b=75, c=100), term="high")
T_5 = FuzzySet(function=Triangular_MF(a=75, b=100, c=100), term="veryhigh")
LV3 = LinguisticVariable([T_1,T_2,T_3,T_4,T_5], concept=" Output Performance", universe_of_discourse=[0,100])
FS.add_linguistic_variable("Op", LV3)
LV3.plot()
# Define fuzzy rules
R1 = "IF (Fsp IS verylow) AND (Ssp IS verylow) THEN (Op IS verylow)"
R2 = "IF (Fsp IS verylow) AND (Ssp IS low) THEN (Op IS verylow)"
R3 = "IF (Fsp IS verylow) AND (Ssp IS average) THEN (Op IS low)"
R4 = "IF (Fsp IS verylow) AND (Ssp IS high) THEN (Op IS low)"
R5 = "IF (Fsp IS verylow) AND (Ssp IS veryhigh) THEN (Op IS average)"
R6 = "IF (Fsp IS low) AND (Ssp IS verylow) THEN (Op IS verylow)"
R7 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS low) AND (Ssp IS average) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS average)"
R10 = "IF (Fsp IS low) AND (Ssp IS veryhigh) THEN (Op IS average)"
R11 = "IF (Fsp IS average) AND (Ssp IS verylow) THEN (Op IS low)"
R12 = "IF (Fsp IS average) AND (Ssp IS low) THEN (Op IS low)"
R13 = "IF (Fsp IS average) AND (Ssp IS average) THEN (Op IS average)"
R14 = "IF (Fsp IS average) AND (Ssp IS high) THEN (Op IS high)"
R15 = "IF (Fsp IS average) AND (Ssp IS veryhigh) THEN (Op IS high)"
R16 = "IF (Fsp IS high) AND (Ssp IS verylow) THEN (Op IS low)"
R17 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS average)"
R18 = "IF (Fsp IS high) AND (Ssp IS average) THEN (Op IS high)"
R19 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R20 = "IF (Fsp IS high) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
R21 = "IF (Fsp IS veryhigh) AND (Ssp IS verylow) THEN (Op IS average)"
R22 = "IF (Fsp IS veryhigh) AND (Ssp IS low) THEN (Op IS high)"
R23 = "IF (Fsp IS veryhigh) AND (Ssp IS average) THEN (Op IS high)"
R24 = "IF (Fsp IS veryhigh) AND (Ssp IS high) THEN (Op IS veryhigh)"
R25 = "IF (Fsp IS veryhigh) AND (Ssp IS veryhigh) THEN (Op IS veryhigh)"
FS.add_rules([R1, R2, R3, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21, R22, R23, R24, R25])
# Set antecedents values
FS.set_variable("Fsp", 40)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 35)
# Perform Mamdani inference and print output
print(FS.Mamdani_inference(["Op"]))
```

```
{'Op': 63.69562470024255}
{'Op': 24.381282408751655}

FS.set_variable("Fsp", 40)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 63.69562470024255}

FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
{'Op': 24.381282408751655}

FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 74.99994984964923}
FS.set_variable("Fsp", 10)
FS.set_variable("Ssp", 20)
print(FS.Mamdani_inference(["Op"]))
{'Op': 20.57958930183036}
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 67.63154357817368}
FS.set_variable("Fsp", 34)
FS.set_variable("Ssp", 60)
print(FS.Mamdani_inference(["Op"]))
{'Op': 62.4998872746616}
FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 52.99268456289116}
FS.set_variable("Fsp", 56)
FS.set_variable("Ssp", 90)
print(FS.Mamdani_inference(["Op"]))
{'Op': 75.6975562875229}
FS.set_variable("Fsp", 74)
FS.set_variable("Ssp", 70)
print(FS.Mamdani_inference(["Op"]))
{'Op': 75.7914539314429}
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 43.96552934663616}
FS.set_variable("Fsp", 65)
```

```
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 57.4789463078331}
FS.set_variable("Fsp", 89)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))
{'Op': 90.572547678132}
FS.set_variable("Fsp", 100)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))
{'Op': 91.6999834165503}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
{'Op': 38.695674850593235}
FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 47.280184293555315}
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.017353869691014}
FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 25)
print(FS.Mamdani_inference(["Op"]))
{'Op': 31.03452080371465}
FS.set_variable("Fsp", 84)
FS.set_variable("Ssp", 80)
print(FS.Mamdani_inference(["Op"]))
{'Op': 77.63868904940428}
FS.set_variable("Fsp", 63)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 75.25516523042124}
FS.set_variable("Fsp", 28)
FS.set_variable("Ssp", 30)
print(FS.Mamdani_inference(["Op"]))
{'Op': 24.208546068557123}
```

## Code used for implementation of Existing Method:

```
#Yadav,Soni and Pal Method
! pip install simpful
#A Mamdani FIS for the Yadav,Soni and Pal Method, defined in Simpful.
from simpful import *
```

```
# A simple fuzzy inference system for the Yadav,Soni and Pal Method
# Create a fuzzy system object
FS = FuzzySystem()
# Define fuzzy sets and linguistic variables
S_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
S_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
S_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV1 = LinguisticVariable([S_1,S_2,S_3], concept="First Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Fsp", LV1)
LV1.plot()
F_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
F_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
F_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV2 = LinguisticVariable([F_1,F_2,F_3], concept="Second Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Ssp", LV2)
LV2.plot()
# Define output fuzzy sets and linguistic variable
T_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
T_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
T_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV3 = LinguisticVariable([T_1,T_2,T_3], concept="Output Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Op", LV3)
LV3.plot()
# Define fuzzy rules
R1 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"
R2 = "IF (Fsp IS high) AND (Ssp IS medium) THEN (Op IS medium)"
R3 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS medium)"
R4 = "IF (Fsp IS medium) AND (Ssp IS high) THEN (Op IS high)"
R5 = "IF (Fsp IS medium) AND (Ssp IS medium) THEN (Op IS medium)"
R6 = "IF (Fsp IS medium) AND (Ssp IS low) THEN (Op IS low)"
R7 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS medium)"
R8 = "IF (Fsp IS low) AND (Ssp IS medium) THEN (Op IS low)"
R9 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"

FS.add_rules([R1, R2, R3, R4, R5, R6, R7, R8, R9])
# Set antecedents values
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 40)
# Perform Mamdani inference and print output
print(FS.Mamdani_inference(["Op"]))
```

```
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 35)
FS.set_variable("Ssp", 20)
print(FS.Mamdani_inference(["Op"]))
{'Op': 18.752742068285773}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 10)
print(FS.Mamdani_inference(["Op"]))
{'Op': 15.5296343359031}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 60)
FS.set_variable("Ssp", 34)
print(FS.Mamdani_inference(["Op"]))
{'Op': 30.604688455023776}

FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 48)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}

FS.set_variable("Fsp", 90)
FS.set_variable("Ssp", 56)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999994}

FS.set_variable("Fsp", 70)
FS.set_variable("Ssp", 74)
print(FS.Mamdani_inference(["Op"]))
{'Op': 82.40611967027063}

FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}

FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}
FS.set_variable("Fsp", 100)
```

```
FS.set_variable("Ssp", 89)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}
FS.set_variable("Fsp", 35)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.000000000000014}
FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 48)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999995}
FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
FS.set_variable("Fsp", 25)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 16.51302166668233}
FS.set_variable("Fsp", 80)
FS.set_variable("Ssp", 84)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 63)
print(FS.Mamdani_inference(["Op"]))
{'Op': 62.02673813975384}
FS.set_variable("Fsp", 30)
FS.set_variable("Ssp", 28)
print(FS.Mamdani_inference(["Op"]))
{'Op': 17.593880329729373}
FS.set_variable("Fsp", 40)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999996}
FS.set_variable("Fsp", 70)
FS.set_variable("Ssp", 66)
print(FS.Mamdani_inference(["Op"]))
{'Op': 69.3953115449761}
```

## Code used for implementation of proposed Modified Method:

```
#Proposed Modified Method
! pip install simpful
#A Mamdani FIS for the Proposed Modified Method, defined in Simpful.
from simpful import *
# A fuzzy inference system for the Proposed Modified Method
# Create a fuzzy system object
FS = FuzzySystem()
# Define fuzzy sets and linguistic variables
S_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
S_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
S_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV1 = LinguisticVariable([S_1,S_2,S_3], concept="First Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Fsp", LV1)
LV1.plot()
F_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
F_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
F_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV2 = LinguisticVariable([F_1,F_2,F_3], concept="Second Semester Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Ssp", LV2)
LV2.plot()
# Define output fuzzy sets and linguistic variable
T_1 = FuzzySet(function=Trapezoidal_MF(a=0, b=0, c=20, d=40), term="low")
T_2 = FuzzySet(function=Triangular_MF(a=30, b=50, c=70), term="medium")
T_3 = FuzzySet(function=Trapezoidal_MF(a=60, b=80, c=100, d=100), term="high")
LV3 = LinguisticVariable([T_1,T_2,T_3], concept="Output Performance",
universe_of_discourse=[0,100])
FS.add_linguistic_variable("Op", LV3)
LV3.plot()
# Define fuzzy rules
R1 = "IF (Fsp IS low) AND (Ssp IS low) THEN (Op IS low)"
R2 = "IF (Fsp IS low) AND (Ssp IS medium) THEN (Op IS medium)"
R3 = "IF (Fsp IS low) AND (Ssp IS high) THEN (Op IS high)"
R4 = "IF (Fsp IS medium) AND (Ssp IS low) THEN (Op IS low)"
R5 = "IF (Fsp IS medium) AND (Ssp IS medium) THEN (Op IS medium)"
R6 = "IF (Fsp IS medium) AND (Ssp IS high) THEN (Op IS high)"
R7 = "IF (Fsp IS high) AND (Ssp IS low) THEN (Op IS low)"
R8 = "IF (Fsp IS high) AND (Ssp IS medium) THEN (Op IS medium)"
R9 = "IF (Fsp IS high) AND (Ssp IS high) THEN (Op IS high)"

FS.add_rules([R1, R2, R3, R4, R5, R6, R7, R8, R9])
# Set antecedents values
```

```
FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 55)
# Perform Mamdani inference and print output
print(FS.Mamdani_inference(["Op"]))
```

{'Op': 50.00000000000001}

```
FS.set_variable("Fsp", 40)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}

FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
{'Op': 33.74039692737309}

FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}

FS.set_variable("Fsp", 10)
FS.set_variable("Ssp", 20)
print(FS.Mamdani_inference(["Op"]))
{'Op': 15.5296343359031}

FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}

FS.set_variable("Fsp", 34)
FS.set_variable("Ssp", 60)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.000000000000206}

FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}

FS.set_variable("Fsp", 56)
FS.set_variable("Ssp", 90)
print(FS.Mamdani_inference(["Op"]))
{'Op': 83.27789649945896}
FS.set_variable("Fsp", 74)
```

```
FS.set_variable("Ssp", 70)
print(FS.Mamdani_inference(["Op"]))
{'Op': 82.40611967027063}
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}

FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}

FS.set_variable("Fsp", 89)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}

FS.set_variable("Fsp", 100)
FS.set_variable("Ssp", 100)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}

FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 35)
print(FS.Mamdani_inference(["Op"]))
{'Op': 33.74039692737309}

FS.set_variable("Fsp", 48)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999995}

FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 25)
print(FS.Mamdani_inference(["Op"]))
{'Op': 16.51302166668233}
FS.set_variable("Fsp", 84)
FS.set_variable("Ssp", 80)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}
FS.set_variable("Fsp", 63)
FS.set_variable("Ssp", 65)
```

```
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}
FS.set_variable("Fsp", 28)
FS.set_variable("Ssp", 30)
print(FS.Mamdani_inference(["Op"]))
{'Op': 17.593880329729373}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 40)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 35)
FS.set_variable("Ssp", 20)
print(FS.Mamdani_inference(["Op"]))
{'Op': 18.752742068285773}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 20)
FS.set_variable("Ssp", 10)
print(FS.Mamdani_inference(["Op"]))
{'Op': 15.5296343359031}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.999999999999964}
FS.set_variable("Fsp", 60)
FS.set_variable("Ssp", 34)
print(FS.Mamdani_inference(["Op"]))
{'Op': 30.604688455023776}
FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 48)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
FS.set_variable("Fsp", 90)
FS.set_variable("Ssp", 56)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999994}
FS.set_variable("Fsp", 70)
FS.set_variable("Ssp", 74)
print(FS.Mamdani_inference(["Op"]))
{'Op': 82.40611967027063}
FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
```

```
FS.set_variable("Fsp", 45)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}
FS.set_variable("Fsp", 100)
FS.set_variable("Ssp", 89)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}
FS.set_variable("Fsp", 35)
FS.set_variable("Ssp", 65)
print(FS.Mamdani_inference(["Op"]))
{'Op': 66.25960307262692}

FS.set_variable("Fsp", 50)
FS.set_variable("Ssp", 48)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999995}
FS.set_variable("Fsp", 55)
FS.set_variable("Ssp", 45)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
FS.set_variable("Fsp", 25)
FS.set_variable("Ssp", 55)
print(FS.Mamdani_inference(["Op"]))
{'Op': 50.00000000000001}
FS.set_variable("Fsp", 80)
FS.set_variable("Ssp", 84)
print(FS.Mamdani_inference(["Op"]))
{'Op': 84.47036566409695}
FS.set_variable("Fsp", 65)
FS.set_variable("Ssp", 63)
print(FS.Mamdani_inference(["Op"]))
{'Op': 62.02673813975384}
FS.set_variable("Fsp", 30)
FS.set_variable("Ssp", 28)
print(FS.Mamdani_inference(["Op"]))
{'Op': 17.593880329729373}
FS.set_variable("Fsp", 40)
FS.set_variable("Ssp", 50)
print(FS.Mamdani_inference(["Op"]))
{'Op': 49.99999999999996}
FS.set_variable("Fsp", 70)
FS.set_variable("Ssp", 66)
print(FS.Mamdani_inference(["Op"]))
{'Op': 69.3953115449761}
```