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Evaluation of Student's Performance using Fuzzy Logic

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Abstract- Educational systems employ a variety of engaging and demanding methods to assess student performance. A Traditional and Fuzzy method are used to evaluate student's performance and comparative analysis is performed on it. Monitoring students' academic progress is a vital concern within the higher education academic community. These strategies or approaches may contribute to enhancing the evaluation process standards of educational institutions. Within this framework, student performance undergoes assessment via a fuzzy inference system (FIS), which analyzes input variables. Data processing and implementation are integrated into the concept of a fuzzy expert system. Gaussian and Trapezoidal membership functions are employed for input variables, while Trapezoidal membership functions are utilized for output. Additionally, a case study is incorporated to boost the validity of this approach. The MATLAB software is utilized to assess the performance of students enrolled in Diploma Engineering at Sal Education Campus, located in Ahmedabad, India. Utilized by academic institutions, this assessment model yields superior outcomes in performance evaluation. Defuzzification is applied to translate data into clear-cut outputs. Fuzzy logic evaluation techniques offer a range of evaluation options, distinguishing them from the traditional approach of consistent mathematical evaluation methods. These applications benefit educators and students alike, enhancing the overall quality of education.

Index Terms- Fuzzy Inference System ,Fuzzy Logic, Membership Function ,Performance Evaluation

1. INTRODUCTION

In the field of education, accurate assessment of student performance is essential to guide academic success and create effective instructional strategies. Traditional assessment methods often struggle to capture the nuances of student learning. However, the integration of fuzzy logic principles offers a promising way to overcome these limitations and create a more comprehensive assessment framework. The purpose of this paper is to explore the application of fuzzy logic in student performance assessment and introduce a new approach which uses its own properties like flexibility and adaptability of fuzzy systems. By incorporating fuzzy sets, membership functions and inference mechanisms, we can develop advanced models that can account for the uncertainty and ambiguity inherent in training data. With this introduction, we lay the groundwork for deeper exploration of the system, the revolutionary potential of fuzzy logic in assessment of student performance. By embracing the principles of fuzzy logic, educators and researchers can unlock new insights into student learning processes, resulting in more accurate assessments and tailored interventions. Delving into the following sections of this article, we explore the theoretical basis of fuzzy logic, explore its practical application in student performance assessment, and discuss its implications for educational practice and policy.

1.1 EVALUATING STUDENT'S PERFORMANCE : A COMPREHENSIVE LOOK

Ramya S. & Jayashree E. elaborates Fuzzy logic is applied in various fields like control systems, decision making, pattern recognition, signal processing, etc. It mimics how humans make decisions. The key elements of a fuzzy logic system are the rule base, fuzzification, inference engine and defuzzification. The rule base contains linguistic rules defined by experts. Fuzzification converts crisp inputs into fuzzy sets. The inference engine applies the rules to fuzzy inputs and defuzzification converts fuzzy outputs into crisp values. Fuzzy logic provides flexibility and can handle imprecise and uncertain data, making it useful for solving real-world problems involving ambiguity.[1] Praveen Kumar & Gopal Singh in their paper proposes fuzzy logic techniques to evaluate student performance and compares the results with classical methods. Fuzzy expert system and fuzzy inference system are used for the student performance evaluation according to input variables like class attendance, assignment marks, internal marks and external marks. Gaussian and trapezoidal membership functions are used to convert crisp input data into fuzzy sets for the input variables. Trapezoidal membership functions are used for the output. The centre of gravity method is used for defuzzification to get a crisp output value. Rules are created based on the input and output membership functions. The results show that fuzzy logic methods give better performance evaluation compared to the classical method. Among the fuzzy logic methods gives more precise results with a lower RMSE value.[2] Ashwani Kharola et. al. in their paper presents a fuzzy logic reasoning based approach for evaluating student performance that considers both academic and personality traits. A stage-wise fuzzy reasoning approach is used to avoid the problem of rule explosion. The proposed fuzzy approach allows for allocating different weights to attributes compared to the traditional average technique. Five experiments were conducted using different attribute values to compare the fuzzy and average methods. The results show the advantage of the fuzzy approach in giving a more balanced rating based on attribute weights. The fuzzy logic approach gives ratings close to the average method, mimicking its behavior while overcoming some of its limitations. The proposed fuzzy model can be refined further and used for evaluating the performance of employees and faculty. Other optimization techniques can also be employed.[3] Shruti S Jamsandekar & R.R Mudholkar in their paper discusses evaluating student's academic performance using fuzzy logic instead of traditional statistical methods. Fuzzy logic can handle imprecise data and human reasoning better than traditional methods. A fuzzy inference system is proposed with triangular and trapezoidal membership functions for inputs and outputs. Fuzzy rules are defined based on expert knowledge to evaluate student performance. The results show that fuzzy logic produces a smoother distribution of student performance compared to traditional methods. Fuzzy logic can help identify students on the border of two classes and provide timely guidance. Including or excluding lab marks affects student performance classification, indicating lab work is important. Subject-wise performance evaluation can be used to track individual student progress and design bridge courses Neuro-fuzzy systems and intelligent tutoring systems can further improve student performance evaluation.[4] Nia Amelia et. al. experiment sample sizes used in the studies varied from 9 to 1121 students. Fuzzy logic methods were found to be useful for predicting student academic performance. Comparative analysis methods were commonly used data type in the studies. Fuzzy set theory, fuzzy rules based, fuzzy inference system, and fuzzy expert system were the most common fuzzy techniques. Around 97% of the studies reported positive effects of fuzzy logic methods in improving student performance assessment. Overall, fuzzy logic methods can help support teachers and improve student learning processes.[5]

Mrinmoy Dam & Debasish Majumder discusses a performance evaluation model based on fuzzy logic to measure the cognitive knowledge and skills acquired by students according to Bloom's taxonomy. The cognitive domain of revised Bloom's taxonomy consisting of six levels - remembering, understanding, applying, analyzing, evaluating & creating are considered as performance indicators. Fuzzy set theory and fuzzy logic are used to handle the vagueness and imprecise data involved in the student performance evaluation process. A Mamdani fuzzy inference system is developed with fuzzy IF-THEN rules to model the relationship between input & output parameters. The input variables considered are the six levels of cognitive domain and the output variable is the student's performance in the cognitive domain. Trapezoidal membership functions are used to represent the linguistic variables and the max-min inference method is adopted for the fuzzy reasoning process. The results show that the proposed fuzzy logic approach can provide a more comprehensive measure of student performance by considering different levels compared to only exam marks.[6] Malatesh Akkur & D.H. Rao used Three parameters are used: internal assessment, theory marks, and practical marks. The crisp values of these parameters are converted to fuzzy parameters and evaluated using a fuzzy inference system. Fuzzy logic can handle a larger number and variety of parameters compared to the traditional evaluation method. The fuzzy inference system can be developed and implemented based on student performance in different subjects and related parameters. In this paper, the fuzzy inference method is used to evaluate student performance based on internal assessment, theory marks, and practical marks. The fuzzy system consists of fuzzification, fuzzy rule base, inference engine and defuzzification. Crisp input values are converted to fuzzy sets using membership functions. Fuzzy rules are formulated based on the importance given to different input parameters by experts. The inference engine matches the fuzzified inputs with the fuzzy rules to generate output. The defuzzification method is used to determine the overall performance from the fuzzy output. The experimental results show that the fuzzy expert system provides more analytical results compared to the conventional method and can be used effectively to evaluate student performance.[7]

Akrivi Krouska et. al. presents a novel approach for refining the evaluation of learners' performance in an intelligent tutoring system using fuzzy logic. The fuzzy logic model takes into account several student characteristics like grades, misconceptions, difficulty level of tests, and student effort. The student effort includes grades in tests, attempts made in exams, and social interaction in forums and posts. The kinds of misconceptions made by students like syntax, semantic and logical are also considered which indicate their knowledge level. The fuzzy logic model diagnoses the accuracy of students' grades and suggests changes to make the evaluation more objective. The system was evaluated using t-test and the results show that it provides more accurate and objective grading compared to a conventional assessment tool. The fuzzy logic approach can improve the final grading by considering factors that affect student performance beyond just average grades.[8] Nne R. Saturday et. al. used fuzzy logic to evaluate students' performance based on various factors like academic grades, social skills, scores on reports, supervisor comments, etc. They found that fuzzy logic gives more flexible and accurate results compared to traditional statistical methods. In this text, the authors propose using fuzzy logic to evaluate engineering students' performance based on their scores on the industrial training report, supervisor comments, and defense of report. They compare the crisp value obtained from the fuzzy logic simulation with the result from the traditional mean method. The authors conclude that fuzzy logic is better than the traditional method since the inputs can be weighted using membership functions. They also say that the external supervisor score can help determine students' actual performance.[9] Sanjana Naidu Gedela & Pavan Bodanki proposes a fuzzy logic based approach to evaluate student performance in placement, results evaluation and higher studies. Fuzzy logic mimics human reasoning and is used to handle uncertainties. Three modules are used: 1) Placement module considers marks, communication skills, technical knowledge and backlogs to evaluate placement performance. 2) Result evaluation module takes previous semester marks to predict next semester marks. 3) Higher studies module considers mock test scores, skills and predicts scores in GRE, GMAT. Pearson correlation coefficient is calculated to determine important input parameters. Mamdani fuzzy inference system is used with triangular, trapezoidal and Gaussian membership functions. Maxima defuzzification methods like first of maxima, mean of maxima and last of maxima are suitable for reasoning systems. The proposed fuzzy logic model helps educational institutions evaluate students better and take necessary actions for their improvement.[10]

1.2 METHODOLOGY

1.2.1 EXPERT SYSTEM

Expert systems represent a significant advance in artificial intelligence, providing a structured approach to problem solving and decision making in specific domains. Expert systems play a vital role in research by providing intelligent support for tasks such as data analysis, hypothesis generation and interpretation of results. These systems are designed to mimic the decision-making processes of human experts, using information representation, inference mechanisms, and inference algorithms to generate accurate and understandable conclusions. By leveraging expert systems, researchers can simplify their workflow, improve the quality of their analyses, and discover hidden patterns or relationships in complex data sets. In addition, the adaptability and scalability of expert systems make them valuable tools for various research challenges in different fields and disciplines. As research becomes increasingly data-driven and interdisciplinary, the integration of expert systems offers a promising opportunity to accelerate scientific discovery and innovation.[5] Designing an expert system to evaluate student performance using fuzzy logic involves defining performance criteria, such as exam scores and class participation, and dividing them into linguistic variables like "poor", "fair",” satisfactory” and "superior." Membership functions are then created to represent the degree to which each student's performance falls within these categories. Fuzzy rules, informed by human expertise, describe how input variables relate to the overall performance evaluation. A fuzzy inference engine processes these rules, converting crisp inputs to fuzzy sets, evaluating rules, and ultimately producing a crisp output representing the overall performance evaluation. The system's knowledge base contains customizable rules and functions, while the user interface enables easy input of student data and interpretation of evaluation results. Through testing, validation, and iterative refinement, the system ensures accuracy and relevance, offering educators a tool to assess student performance that accounts for the inherent uncertainty and complexity of educational assessments. An expert system uses metaphorical descriptions (instructions, systems or blueprints) to learn, and replicates their reasoning with representational computation that verifies the mastery of ordinary language.[8]

In this paper, Gaussian and **Trapezoidal membership functions** are used **to transform a crisp** set into **a** fuzzy set. Gaussian and trapezoidal **membership functions represent** the following formulation.

$$\text{Trapezodial}(x,p,q,r,s) = \max\left(\min\left(\frac{x-p}{q-p}, 1, \frac{s-x}{s-r}\right)\right)$$

$$\text{Gaussion}(x,\mu i,\sigma i) \quad = e^{-\frac{(x-\mu i)^{\;2}}{2\sigma_i^2}}$$

The Trapezoidal Membership Function is a key concept in fuzzy logic, serving to model the degree of membership of an element in a fuzzy set. It is particularly useful for representing fuzzy sets with trapezoidal-shaped membership distributions. This function is defined by four parameters, denoted as p, q, r and s, which determine the shape of the trapezoid. The function takes an input x and calculates the degree of membership based on how it falls within the defined trapezoid. Specifically, it linearly increases from p to q, remains constant from q to r, and then linearly decreases from r to s. The result is a smooth transition in membership, providing a flexible tool for capturing uncertainty and vagueness in decision-making processes.

The Gaussian Membership Function, on the other hand, is utilized to represent fuzzy sets with Gaussian or bell-shaped distributions. This function is characterized by two parameters: the mean μi and the standard deviation σi. It calculates the degree of membership for an input x based on its proximity to the mean μi within the Gaussian distribution defined by σi. As x moves away from the mean, the degree of membership decreases symmetrically, reflecting the natural spread of values in the distribution. The Gaussian Membership Function is particularly effective in modeling concepts where values closer to the mean are considered more representative, while those farther away are less so.

1.2.2 MODELLING PROCESS

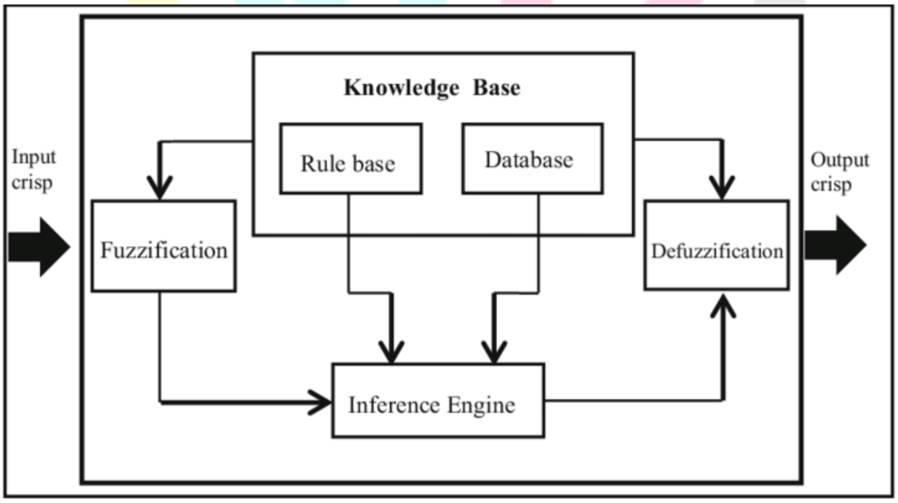


Figure 1: Fuzzy Validation Expert System[3]

The Input Layer represents the input variables or data provided to the system for validation. This layer encompasses various types of data, including measurements, observations, or user input. Fuzzification serves to convert crisp input data into fuzzy sets. This process involves assigning degrees of membership to each input variable across relevant linguistic variables or fuzzy sets.[9] It achieves this by applying membership functions to characterize the degree of truth for each input with respect to different linguistic terms. The Knowledge Base holds the rules, heuristics, or domain knowledge used by the system to evaluate and validate the input data. These rules are typically expressed in the form of IF-THEN statements or fuzzy inference rules, capturing expert knowledge about the validation process. The Inference Engine utilizes the fuzzy rules from the knowledge base to perform fuzzy inference and reasoning. It combines the fuzzy input data with the fuzzy rules to derive conclusions or make decisions regarding the validation of the input. Validation Logic implements the validation logic based on the results of fuzzy inference. This component involves aggregating and analyzing the fuzzy output to determine the overall validity or reliability of the input data. The Output Layer represents the output of the validation process. This layer includes validated results, confidence levels, or recommendations based on the input data and validation logic. Defuzzification is the final step, converting the fuzzy output from the inference engine into crisp values or actionable insights. It is essential for interpreting the fuzzy output in a meaningful way and making it suitable for further processing or decision-making.[6]

1.3 Defuzzification

Defuzzification is crucial for turning the fuzzy output of a fuzzy logic system into a specific decision or recommendation. By choosing a defuzzification method such as centroid or weighted average, the system can provide interpretable and actionable results that facilitate decision making in real-world applications. Basically, defuzzification bridges the gap between fuzzy reasoning and practical decision making by extracting the precise value from the fuzzy result. Through this process, fuzzy logic systems can provide meaningful insights and recommendations that can be easily understood and acted upon by users in various industries.[2]
Defuzzification can be formulated as below:

$$\text{Defuzzified Output} = \frac{\sum_i Centroid_i \; X \; Membership_i}{\sum_i Membership_i}$$

Where:
$Centroid_i$ represents the centroid (or center of gravity) of each fuzzy set in the output.
$Membership_i$ denotes the degree of membership of each fuzzy set.
The sums are taken over all fuzzy sets in the output.
This formula calculates the weighted average of the centroids of each fuzzy set, where the weights are determined by the degree of membership of each set. The resulting value represents the defuzzified output, providing a crisp value that reflects the overall fuzzy output.

2. RESEARCH ELABORATING

To illustrate the process, we consider that five inputs are used to evaluate student performance, viz. Attendance C1, Assignment C2, Practical C3, Mid Exam C4 and Viva C5.

PERFORMANCE EVALUATION MEMBER FUNCTIONS.
Here we use five input parameters and try to find the performance level of the students in the results.

Criteria 1
We made a trapezoidal membership function for the following information.
Poor [0 0 15 30], Fair [15 30 45 60], Satisfactory [45 60 75 90], Superior [75 90 100 100]

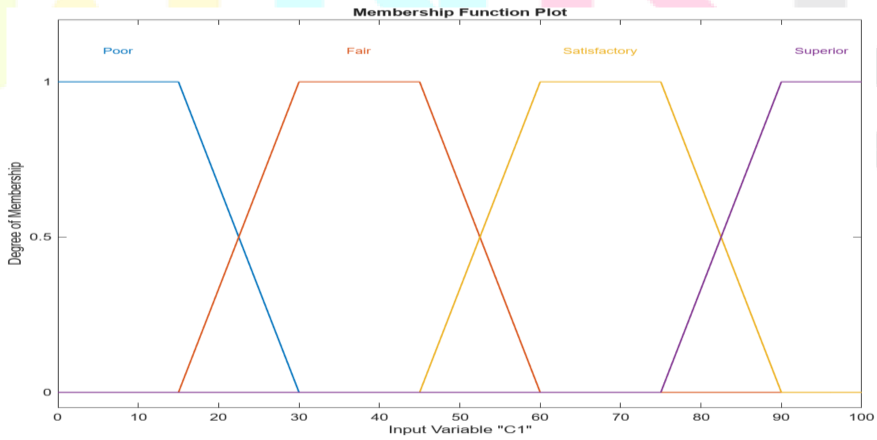


Figure 2: C1 Membership Function

Criteria 2

We made a trapezoidal membership function for the following information.
Poor [0 0 20 30], Fair [20 30 40 50], Satisfactory [40 50 70 80], Superior [70 80 100 100]

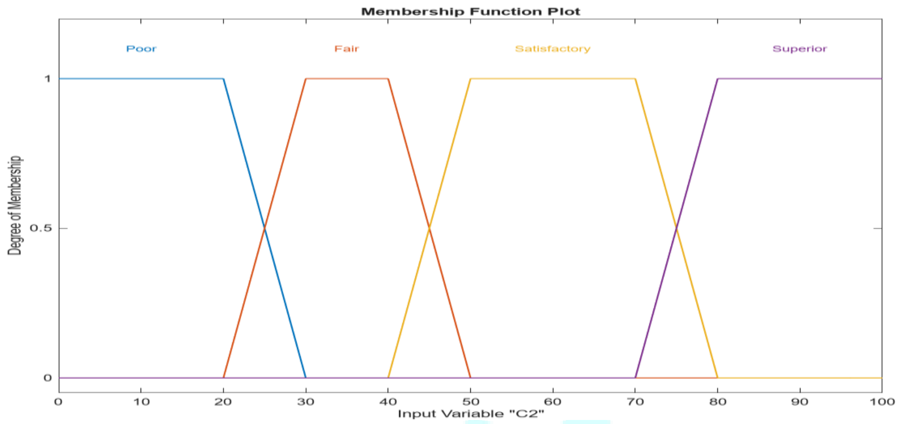


Figure 3: C2 Membership Function

Criteria 3

We made a trapezoidal membership function for the following information.
Poor [0 0 10 30], Fair [10 30 40 60], Satisfactory [40 60 70 80], Superior [70 80 100 100]

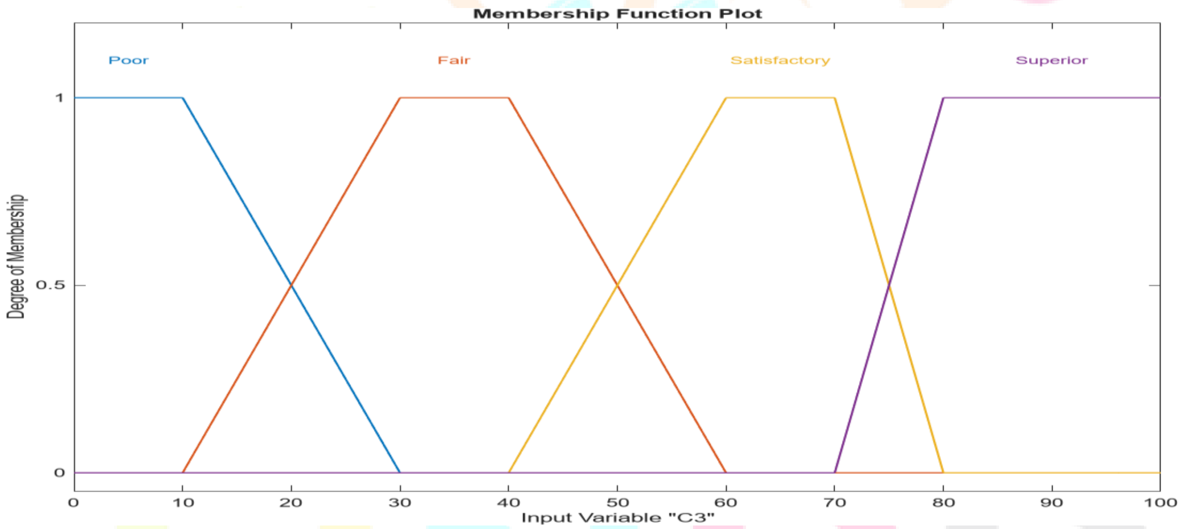


Figure 4: C3 Membership Function

Criteria 4

We made a trapezoidal membership function for the following information.
Poor [0 0 5 25], Fair [5 25 40 50], Satisfactory [40 50 70 85], Superior [70 85 100 100]

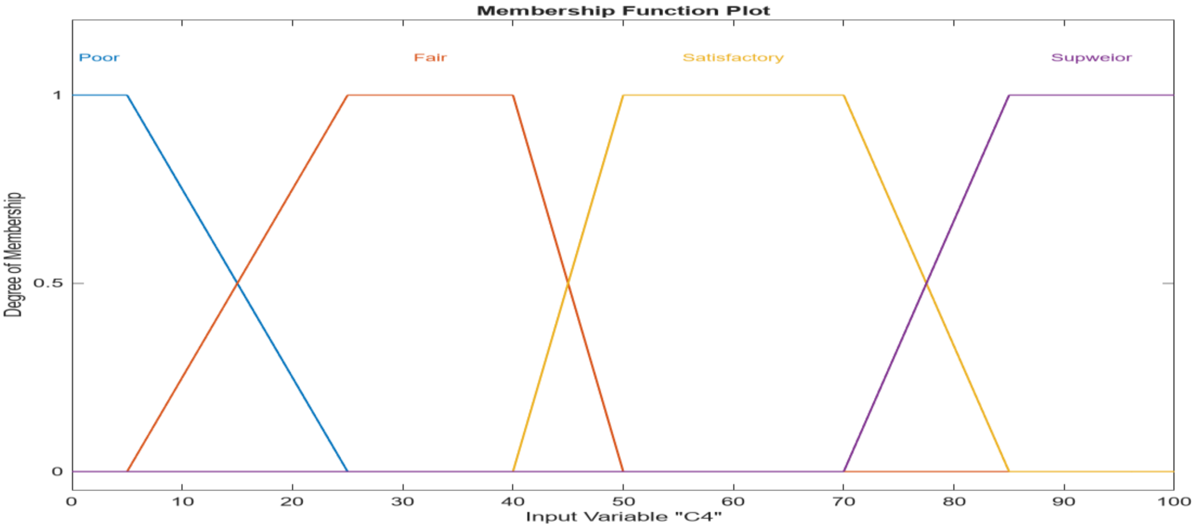


Figure 5: C4 Membership Function

Criteria 5

We made a Gaussian membership function for the following information.
Poor [8 20], Fair [10 40], Satisfactory [7 60], Superior [8 100]

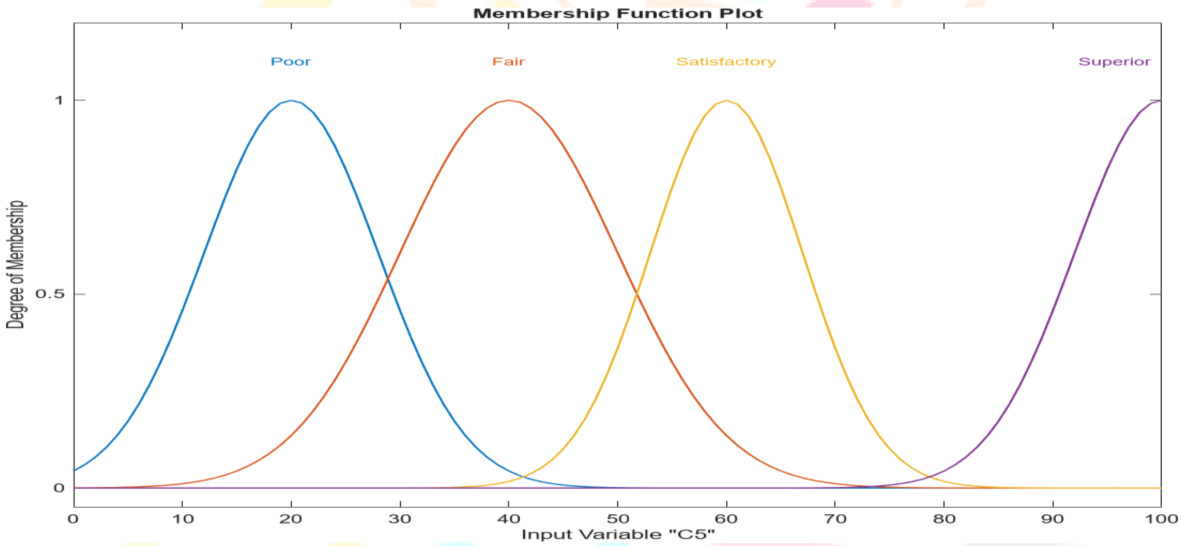


Figure 6: C5 Membership Function

Fuzzy Sets for Output Variable

The fuzzy sets for output variables are shown in trapezoidal membership functions with three stages of performance evaluations (Stage- 1, Stage -2 and Stage-3), Where stages are in better performance as in increasing order. Stage- 1 [0 0 20 30], Stage- 2 [20 30 50 60], stage- 3 [50 60 90 100]

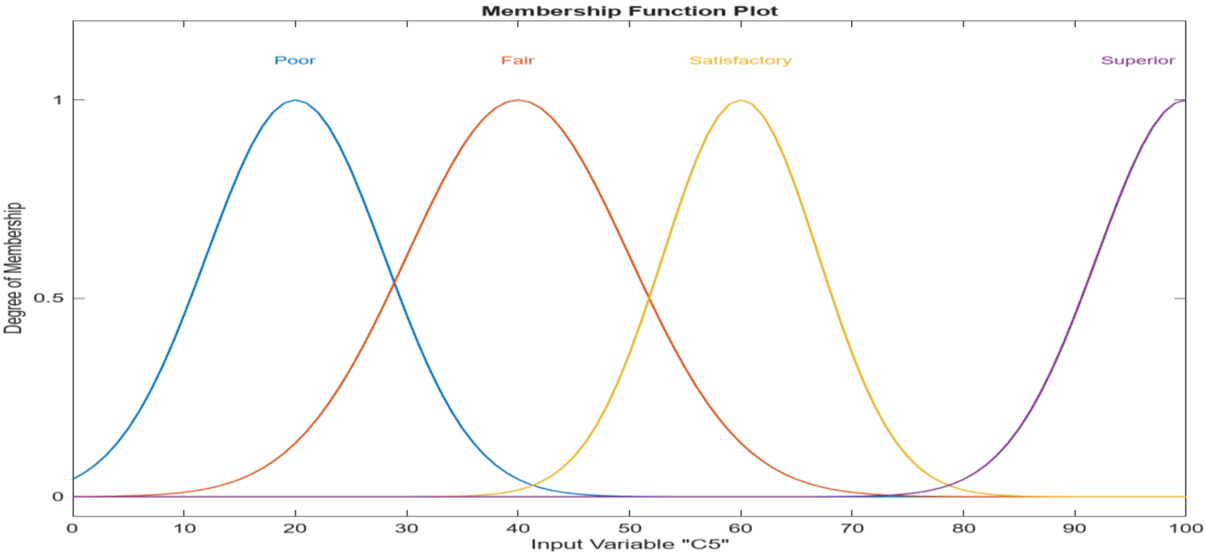


Figure 7 Output Membership Function

Defining Rules

To generate Rules for above input and output membership function following code can be used :

A total of 5 input function are to correspond to 3 outputs, with allowance of repetition the combination of 1024 rules can be generated.

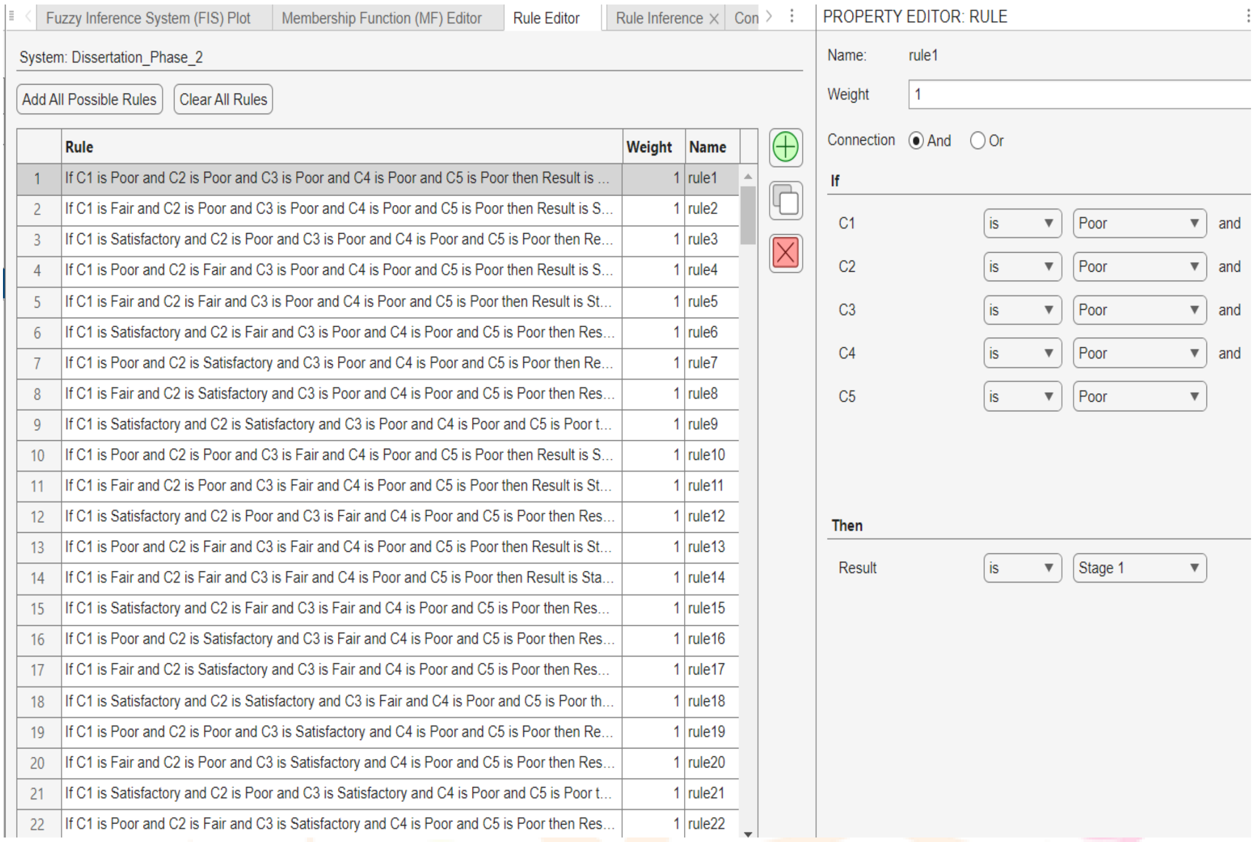
In [3]:
```
from itertools import product

# Define the values for each word
values = {"poor": 25, "fair": 55, "satisfactory": 70, "superior": 100}

# Generate all combinations of the words with repetition allowed
combinations = list(product(values.keys(), repeat=5))

# Calculate the average value for each combination and categorize them into stages
for combination in combinations:
    total_value = sum(values[word] for word in combination)
    average_value = total_value / len(combination)
    if average_value <= 35:
        stage = "Stage 1"
    elif 36 <= average_value <= 65:
        stage = "Stage 2"
    else:
        stage = "Stage 3"
    print(f"Combination: {combination}, Average: {average_value}, Stage: {stage}")
```

Rules Applied:



Snapshot 1: Rule Editor Interface

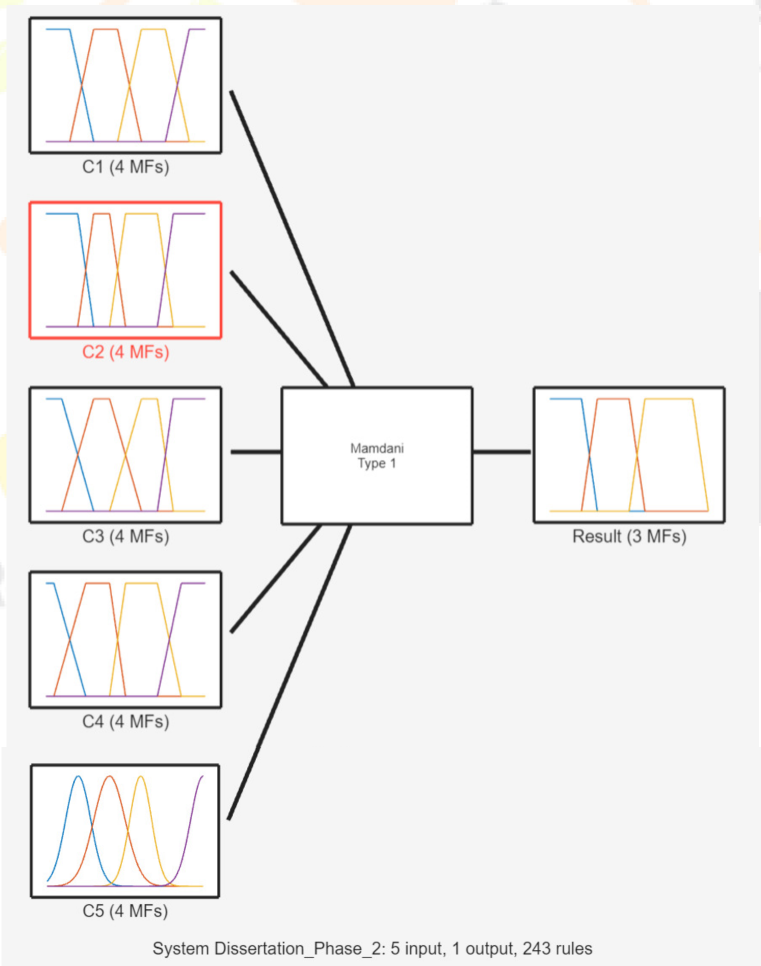


Figure 8: Fuzzy Inference System Plot

3. RESULTS

In the present work, fuzzy expert system is proposed for the student's performance evaluation and calculation and testing is done under the MATLAB. A fuzzy tool also introduced for the research work evaluation and a samples of 10 students from the data is tested in the proposed expert system. Table -1 shows the performance of Diploma in Information Technology Semester 4 students of Sal Institute of Diploma Studies, Opp. Science City, Ahmedabad, Gujarat, India.

S_Id	C1	C2	C3	C4	C5	Traditional Method	Proposed Method
SDI4B_1	51.85	66	62.5	86.67	80	69.404	74.32
SDI4B_2	48.15	44	50	10	20	34.43	38.42
SDI4B_3	37.04	70	75	40	80	60.408	66.87
SDI4B_4	62.96	84	87.5	63.33	60	71.558	74.88
SDI4B_5	81.48	98	100	53.33	60	78.562	84.57
SDI4B_6	70.37	82	100	50	60	72.474	69.56
SDI4B_7	81.48	100	95	100	80	91.296	94.93
SDI4B_8	40.74	50	50	46.67	50	47.482	41.23
SDI4B_9	37.04	50	50	60	10	41.408	34.52
SDI4B_10	92.59	100	100	70	80	88.518	90.12

Table 1: Scores of Performance of 10 Students

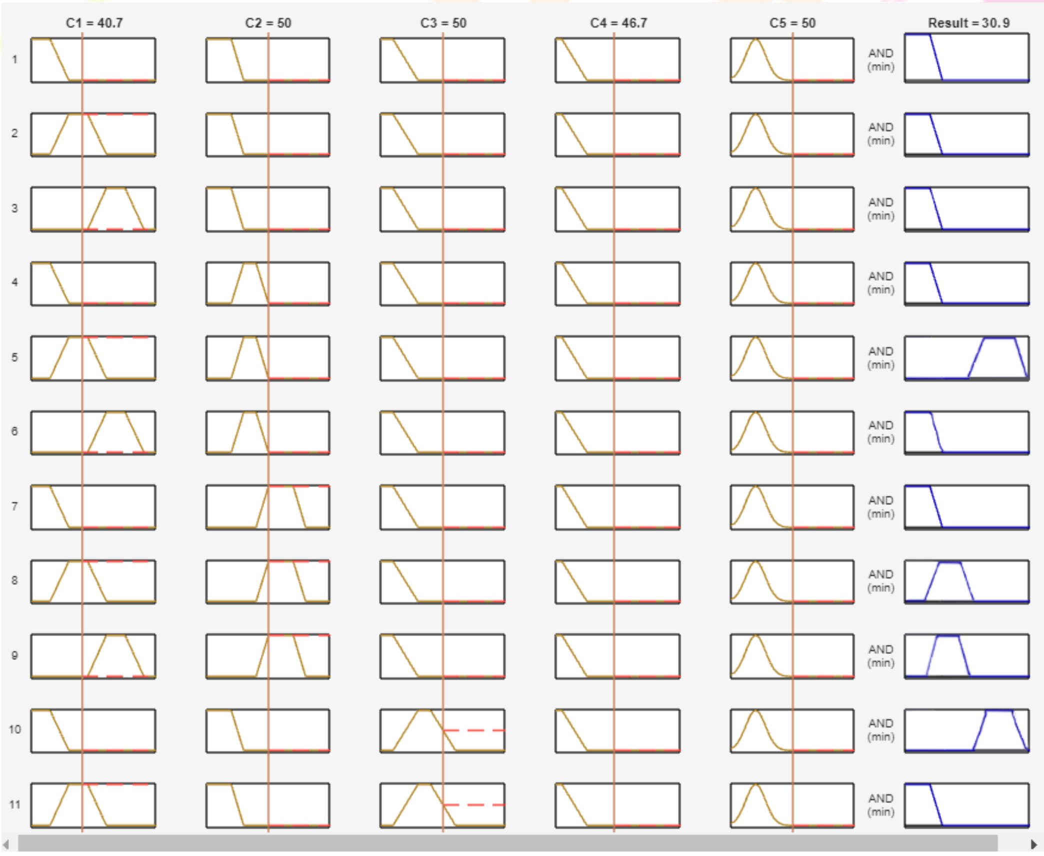


Figure 9 : Rules Inference Graphs

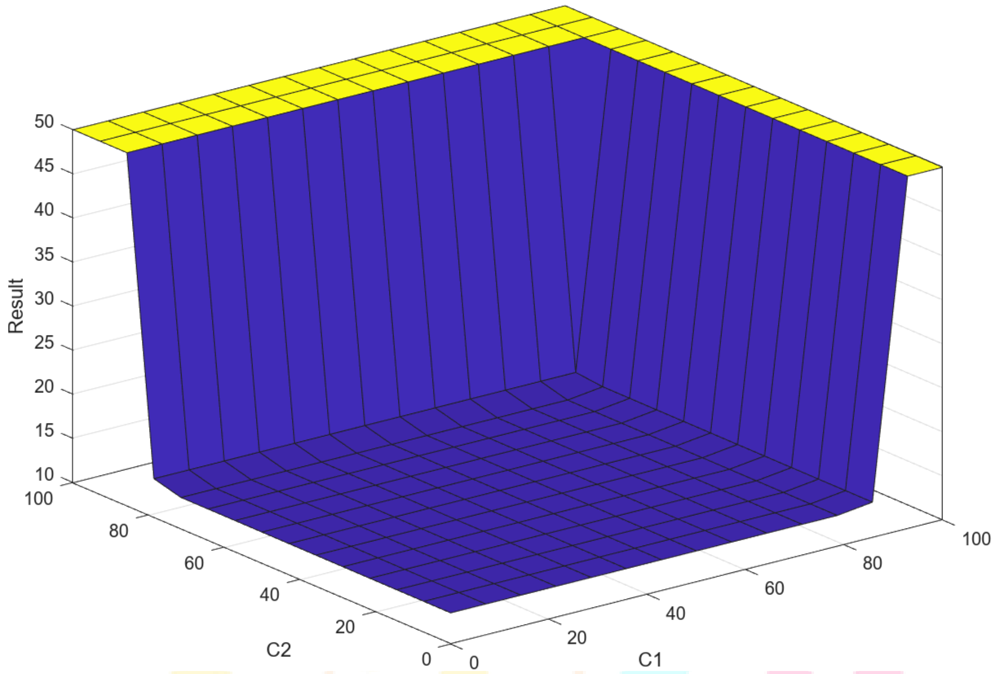


Figure 10: Surface Viewer Graph

Sr. No.	Training & Testing (RMSE)	Modelling Student's Performance	Evaluation of Student's Performance
1	Testing (RMSE)	0.061	0.049

Table 2: RMSE of Training and Testing Dataset

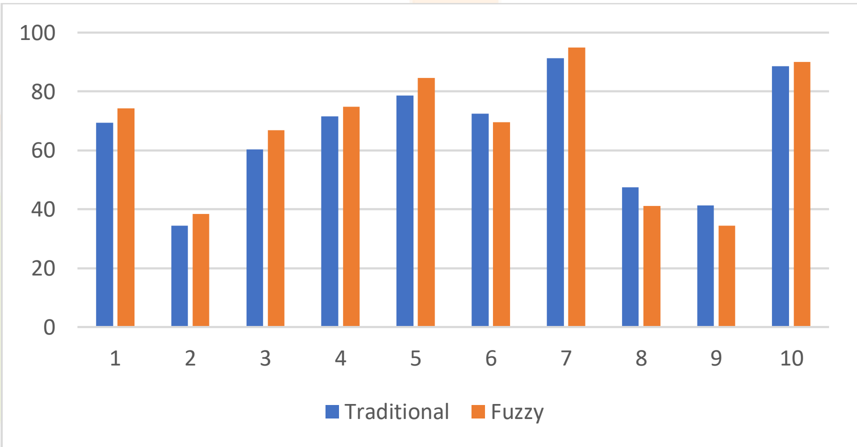


Figure 11: Comparison of performance of students of Traditional and Fuzzy Method

4. CONCLUSION

In this paper, proposed work is calculated under the Madnani Techniques and fuzzy expert system. The scores are divided in 100 marks. The Evaluation of performance according to the input factors are describe in membership function. IF THEN Rules are describing all rules and also Output is taken in 3-stages as stage-1, stage-2 and stage-3 and the better performance as in increasing order. All the results for the performance evaluation can be evaluated or compared from Comparison Chart and Output variable are described earlier. MATLAB is used in the whole calculation for the results. As we have seen that the proposed method (Fuzzy Expert System) is more suitable for students 'performance evaluation in comparison to classical Method.

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