Modeling Academic Performance Evaluation Using Soft Computing Techniques: A Fuzzy Logic Approach

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Abstract-We have proposed a Fuzzy Expert System (FES) for student academic performance evaluation based on fuzzy logic techniques. A suitable fuzzy inference mechanism and associated rule has been discussed. It introduces the principles behind fuzzy logic and illustrates how these principles could be applied by educators to evaluating student academic performance. Several approaches using fuzzy logic techniques have been proposed to provide a practical method for evaluating student academic performance and compare the results (performance) with existing statistical method.

Keywords-Fuzzy Logic, Expert System, Membership Functions, Academic performance Evaluation, Intelligent Tutoring Systems (ITS) and Computer Assisted Instruction (CAI).

1. INTRODUCTION

The use of fuzzy logic approach for academic performance evaluation is in general fairly new. However, it has reached a wide range of application areas in educational systems in addition to evaluation of student academic performance, including the evaluation of curriculum and that of the educators (e.g. lecturers and tutors) [7]. In student performance evaluation in particular, fuzzy techniques have been adapted for evaluation based on numerical scores obtained in an assessment and for assessing prior educational achievement based on evidence such as academic certificates. Much attention has also been given to adopting fuzzy approaches for the evaluation of teaching using a computer, in particular in Intelligent Tutoring Systems (ITS) and Computer Assisted Instruction (CAI). For instance, in fuzzy approaches were proposed for determining the level of a student's understanding of a certain subject matter in the context of ITS, and in a fuzzy approach was proposed to assess student performance based on several criteria with a strong suggestion that the method be applied to CAI [8]. Interesting work has been reported along this line of research. This includes evaluation of journal grades, evaluation of vocational education performance, collaborative assessment, and performance appraisal systems of academics in higher education [3]. The focus of attention of this research work is an evaluation of student academic performance. It proposes the use of a fuzzy logic techniques and fuzzy rule induction approach to obtain user-comprehensible knowledge from historical data to justify any evaluation. This research work shows the advantages of the approach in student performance evaluation as it can be built not only based on information in a given dataset but also allowing expert knowledge to be added if such knowledge is available. Information induced from the dataset, especially that not formerly known by experts in the domain, can be very useful in developing fuzzy models for practical applications [8].

2. RESEARCH PROBLEM

Evaluation of student academic performance usually consists of several components, each involving a number of judgments often based on imprecise data. This imprecision arises from human (teacher/tutor) interpretation of human (students) performance. Arithmetical and statistical methods have been used for aggregating information from these assessment components. These methods have been accepted by many educational institutions around the world although there are limitations with these traditional approaches. In this proposed study, it is argued that the current method of classifying and grading student academic performance using arithmetical and statistical techniques does not necessarily offer the best way to evaluate human acquisition of knowledge and skills. It is expected that reasoning based on fuzzy models will provide an alternative way of handling various kinds of imprecise data, which often reflects the way people think and make judgments.

3. THE AIM AND OBJECTIVE OF THE PROPOSED RESEARCH WORK

The aim and objective of the study is to determine students' performance using a fuzzy logic model in place of classical assessment methods [8]. The study aimed to address the following research questions:

1. Is there any difference between classical and fuzzy logic evaluation methods?
2. Is there any difference in assessment results between classical and fuzzy logic evaluation methods?
3. What are the comments of academics about these two methods?

The objectives of the proposed study are to:

1. Study the application of fuzzy modeling based on previous or current data for classifying student academic performance.
2. Develop a fuzzy rule based Expert System (ES) for such an application, which arithmetical and statistical methods are unable to offer effectively, and which allows inference to be performed in a more natural way using linguistic variables rather than numerical values.
3. Implement experiment on fuzzy rule based Expert System, investigating the effectiveness of the methods in handling multiple attributes, containing imprecise data, to perform human-like reasoning.

4. TOOLS AND TECHNIQUES

4.1. Fuzzy Logic

Fuzzy logic is branch of logic specially designed for representing knowledge and human reasoning in such a way that it is amenable to processing by a computer. Thus, it is applicable to artificial intelligence, control engineering, and expert systems [5]. The more traditional propositional and predicate logic do not allow for degrees of imprecision, indicated by words of phrases such as poor, average and good. Instead of truth values such as true or false, it is possible to introduce a multivalued logic consisting of Unsatisfactory, Satisfactory, Average, Good, and Excellent. Fuzzy systems implement fuzzy logic, which uses sets and predicates of this kind. As the classic logic is the basic of ordinary expert logic, fuzzy logic is also the basic of fuzzy expert system. Fuzzy expert systems, in addition to dealing with uncertainty, are able to model common sense reasoning which is very difficult for general systems. One of the basic limitations of classic logic is that it is restricted to two values, true or false and its advantage is that it is easy to model the two-value logic systems and also we can have a precise deduction. The major shortcoming of this logic is that, the number of the two-value subjects in the real world is few. The real world is an analogical world not a numerical one. We can consider fuzzy logic as an extension of a multi-value logic, but the goals and application of fuzzy logic is different from multi-value logic since fuzzy logic is a relative reasoning logic not a precise multi-value logic. In general, approximation or fuzzy reasoning is the deduction of a possible and imprecise conclusion out of a possible and imprecise initial set.

4.2. Fuzzy Set

A fuzzy set A in a universe of discourse X is defined as the following set pairs

$$A = \{(\mu_A(x) : x \in X\} \qquad (1)$$

Where, $\mu_A(x) : X \to [0,1]$ is a mapping called the membership function of fuzzy set *A* and $\mu_A(x)$ is called the degree of belongingness or membership value or degree of membership of $x \in X$ in the fuzzy set *A.* we write (1) in the following form:

$$A = \{\mu_A(x) / x : x \in X\} \qquad (2)$$

For brevity, however, we often equate fuzzy sets with their membership functions i.e. instead of a fuzzy set *A* characterized by $\mu_A(x)$ we will often say fuzzy sets μ_A [4, 8].

Example**:** Suppose *X* = {6, 2, 0, 4}. A fuzzy set of *X* may be given by *A* = {0.2/6, 1/2, 0.8/0, 0.1/4}.

4.3. Membership Function

In this paper we have used the triangular membership function for converting the crisp set into fuzzy set. A triangular membership function is specified by three parameters (a, b, c) as follows [8] is shown in Figure 1:

$$triangular(x:a,b,c)=\begin{cases}0 & x<a \\ x-a/b-a & a\le x\le b \\ c-x/c-b & b\le x\le c \\ 0 & x>c\end{cases} \quad (3)$$

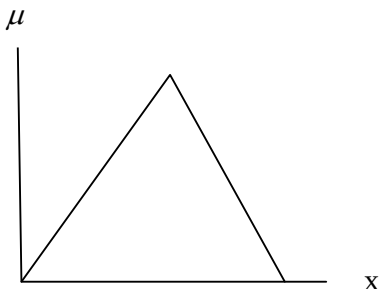

Figure 1: Triangular Membership Function

Due to their simple formula and computational efficiency, the triangular membership function have proven popular with fuzzy logic and been used extensively in student academic performance evaluation [8]. In this paper, we have used only triangular membership function.

4.4. Expert System

An Expert System is a set of program that manipulates encoded knowledge to solve problem in a specialized domain that normally requires human expertise [1]. Expert System knowledge is obtained from expert sources and coded in a form suitable for the system to use in its inference or reasoning processes. The expert knowledge must be obtained from specialists or other sources of expertise such as texts, journal articles and database. This type of knowledge usually requires much training and experience in some specialized field such as medicine, geology, system configuration, or engineering design. Once a sufficient body of expert knowledge has been acquired, it must be encoded in some form, loaded into a knowledge base, then tested, and refined continuously throughout the life of the system.

Expert system differs from conventional computer system in several important ways:

1. Expert systems use knowledge rather than data to control the solution process.
2. The knowledge is encoded and maintained as an entirely separate from the control program.
3. Expert systems are capable of explaining how a particular conclusion was reached, and why requested information is needed during a conclusion.
4. Expert system use symbolic representations for knowledge (rules, networks, or frames) and perform their inference through symbolic computation that closely resemble manipulations of natural language.

5. PROPOSED METHOD FOR ACADEMIC PERFORMANCE EVALUATION

One of the drawbacks of the current academic evaluation methods is the lack of information behind the evaluation methods that have been used and what criteria for the 'final result'. To do so, a fuzzy approach has been used to perform the proposed method of student performance evaluation. It is important to point out that the aim of the proposed method is not to replace the current traditional method of evaluation, instead it will strengthen the present system by providing additional information to be used for decision making by the user. Figure 2 shows the proposed method (fuzzy Expert System) of student academic performance evaluation.

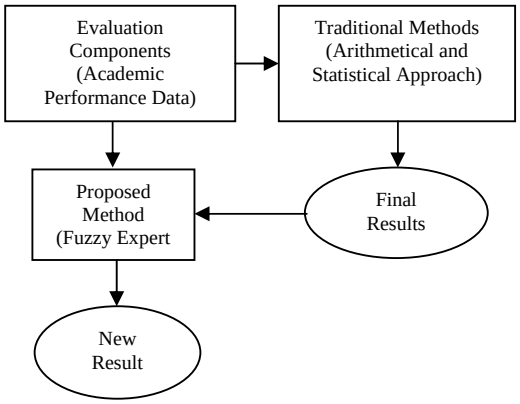

Figure 2: Proposed Method (Fuzzy Expert System) for Academic Performance Evaluation

6. ARCHITECTURE OF PROPOSED FUZZY EXPERT SYSTEM

The architecture of proposed Fuzzy Expert System for academic performance evaluation is given bellow (shown in Figure 3):

1. Crisp Value*:* Crisp value is student mark obtained in semester's examination.
2. Fuzzification*:* Fuzzification means crisp value (student mark) is converted into Fuzzy input value with help of suitable membership function (triangular membership function).
3. Inference Mechanism*:* Define different type fuzzy rule ("If Then" Rule) for student academic performance evaluation.
4. Fuzzy Output*:* Determines an output membership function value for each active rule ("If Then" rule).
5. Defuzzification (Performances*):* Defuzzification means calculate the final output (Performance Value) with the help suitable defuzzification method. In this research work, we have used Centre of Area (COA) for Defuzzification (performance evaluation).

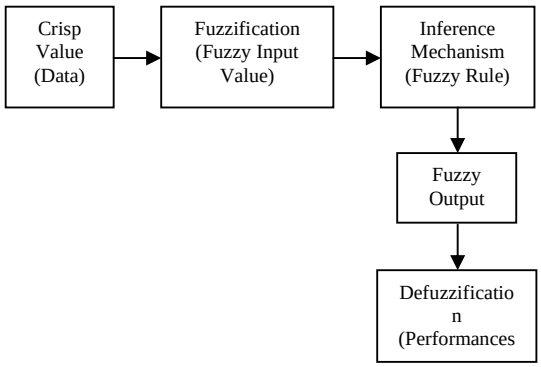

Figure 3: Architecture of Proposed Expert System for Student Academic Performance Evaluation

7. FUZZY EXPERT SYSTEM FOR ACADEMIC PERFORMANCE EVALUATION

In this paper, we have proposed a Fuzzy Expert System (FES) for student academic performance evaluation is shown in Figure 4:

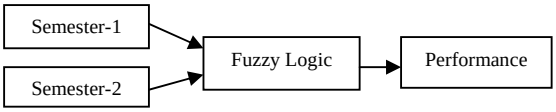

Figure 4: Fuzzy Expert System for Academic Performance Evaluation

Here, students sit semester-1 and semester-2 examination, so there are two input variables say semester-1 and semester-2. The output variable called performance value, which is determined by fuzzy logic.

8. ACADEMIC PERFORMANCE EVALUATION WITH FUZZY EXPERT SYSTEM

Academic Performance Evaluation with Fuzzy Expert System comprised with three steps:
1. Fuzzification of inputs semester examination results and output performance value.
2. Determination of application rules and inference method.
3. Defuzzification of performance value.

8.1. Fuzzification of Semester Examination Results and Performance Value

Fuzzification of semester examination results was carried out using input variables and their membership functions of fuzzy sets. Each student has two semester examination results both of which from input variables of the fuzzy logic based expert system. Each input variable has five triangular membership functions. The fuzzy sets of the input variables are given in Table 1 and different type inputs membership functions are shown in figure 5:

Table 1: Fuzzy set of input variable

Linguistic Variable	Interval
Very Low (VL)	(0, 0, 25)
Low (L)	(0, 25, 50)
Average (A)	(25, 50, 75)
High (H)	(50, 75, 100)
Very High (VH)	(75, 100, 100)

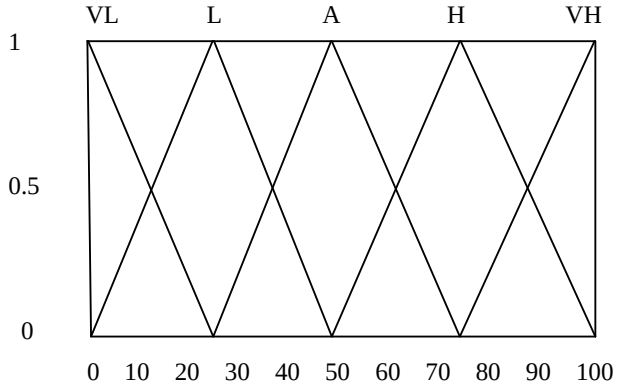

Figure 5: Membership Functions of Semester-1 and Semester-2

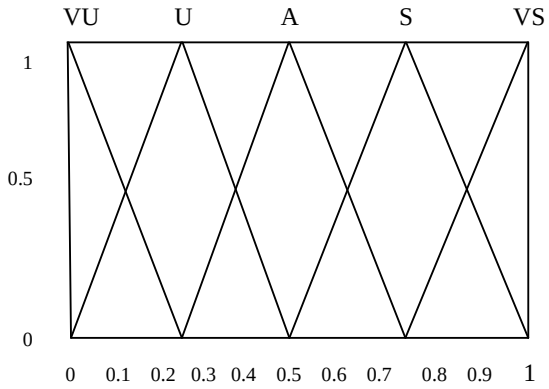

Figure 6: Membership Functions of Performance Value

The output variable, which is the performance value and has five membership functions. The fuzzy set of output variables are shown in Table 2 and different type output membership functions are shown in Figure 6:

Table 2: Fuzzy Set of output variables

Linguistic Variable	Interval
Very Unsuccessful (VU)	(0, 0, 0.25)
Unsuccessful (U)	(0, 0.25, 0.5)
Average (A)	(0.25, 0.5, 0.75)
Successful (S)	(0.5, 0.75, 1)
Very Successful (VS)	(0.75, 1, 1)

8.2. Rules and Inference Generation

The rules determine input and out membership functions that will be used in inference process. These rules are linguistic and are entitled "IF-THEN" RULES:

1. If Semester-1 is VL and Semester-2 is VL then Performance is VU.
2. If Semester-1 is VL and Semester-2 is L then Performance is VU.
3. If Semester-1 is VL and Semester-2 is A then Performance is U.
4. If Semester-1 is VL and Semester-2 is H then Performance is U.
5. If Semester-1 is VL and Semester-2 is VH then Performance is A.
6. If Semester-1 is L and Semester-2 is VL then Performance is VU.
7. If Semester-1 is L and Semester-2 is L then Performance is U.
8. If Semester-1 is L and Semester-2 is A then Performance is U.
9. If Semester-1 is L and Semester-2 is H then Performance is A.
10. If Semester-1 is L and Semester-2 is VH then Performance is A.
11. If Semester-1 is A and Semester-2 is VL then Performance is U.
12. If Semester-1 is A and Semester-2 is L then Performance is U.
13. If Semester-1 is A and Semester-2 is A then Performance is A.
14. If Semester-1 is A and Semester-2 is H then Performance is S.
15. If Semester-1 is A and Semester-2 is VH then Performance is S.
16. If Semester-1 is H and Semester-2 is VL then Performance is U.
17. If Semester-1 is H and Semester-2 is L then Performance is A.
18. If Semester-1 is H and Semester-2 is A then Performance is S.
19. If Semester-1 is H and Semester-2 is H then Performance is S.
20. If Semester-1 is H and Semester-2 is VH then Performance is VS.
21. If Semester-1 is VH and Semester-2 is VL then Performance is A.
22. If Semester-1 is VH and Semester-2 is L then Performance is S.
23. If Semester-1 is VH and Semester-2 is A then Performance is S.
24. If Semester-1 is VH and Semester-2 is H then Performance is VS.
25. If Semester-1 is VH and Semester-2 is VH then Performance is VS.

In case of several rules are active for the same output membership function. It is necessary that only one membership value is chosen. This process is entitled "fuzzy decision" or "fuzzy inference". Several authors, including Mamdami, Takagi_Surgeno and Zadeh have developed a range of techniques for fuzzy decision-making and fuzzy inference [5]. In this paper, we use the method proposed by Mamdami, is given below:

$$\mu_c(y) = \max_k[\min[\mu_A(input(i), \mu_B(input(j))]], \; k = 1, 2, 3, 4\ldots r. \quad (4)$$

This expression determines an output membership function value for each active rule. When one rule is active, an AND operation is applied between inputs. The smaller input value is chosen and its membership value is determined as membership value of the output for that rule. This method is repeated, so that output membership functions are determined for each rule. To sum up, graphically AND (min) operation are applied between inputs and OR (max) operations are between output.

8.3. Calculation of Performance Value

After completing the fuzzy decision process, the fuzzy number obtained must be converted to a crisp value. This process is known as Defuzzification. Many methods have been developed for Defuzzification. In this paper, a centre of area (Centroid) technique was applied, which one of the most common methods [5]. The crisp value is calculated of the formula given below:

$$z = \frac{\int \mu_C(z) \times x \times dz}{\int \mu_C(z) \times dz} \quad (5)$$

9. EXPERIMENT RESULTS

In this research paper, proposed Fuzzy Expert System for student academic performance evaluation has been implemented in MATLAB (version 7.8). We have used Fuzzy Tool for this research work. The proposed Fuzzy Expert System was tested with 20 student's marks obtained by semester-1 and semester-2 examinations. Table 3 shows the scores achieved by 20 MCA III year students in the Department of Computer Science and Applications, MG Kashi Vidyapith Varanasi; sit in semester-1 and semester-2 examinations. For each student, both semester examination scores were fuzzified by means of the triangular membership functions. Active membership functions were calculated according to rule table, using the Mamdami Fuzzy Decision Techniques. The output (Performance Value) was calculated and then defuzzified by calculating the center (centriod) of the resulting geometrical shape. This sequence was repeated using the semester examination scores for each student.

Table 3: Semester scores and calculated performance value (Fuzzy-1)

S. No.	Semester-1	Semester-2	Performance Value
1	40	65	0.530
2	20	35	0.243
3	50	65	0.645
4	10	20	0.203
5	**45**	**65**	**0.576**
6	34	60	0.462
7	48	55	0.533
8	56	90	0.759
9	74	70	0.735
10	45	50	0.440
11	**65**	**45**	**0.576**
12	89	100	0.908
13	100	100	0.920
14	65	35	0.500
15	48	50	0.473
16	45	55	0.500
17	55	25	0.310
18	84	80	0.765
19	63	65	0.639
20	28	30	0.310

Both inputs had same Triangular Membership Functions. Therefore, replacing Semester-1 with Semester-2 would not change the calculated performance value (45 and 65) and (65 and 45). If the symmetry or the value range of the membership functions is not equal, one of the semester examinations has a greater influence on the output performance value than the other. For example, let's change the membership functions and value range of Semester-2 (Figure 7), while retaining the original criteria for semester-1 examination. Surface viewer is shown in figure 8 for student academic performance evaluation. Aim of this study arrangement in semester-2 examination is penalize scores below 50 and to reward scores above 50. This situation can be seen in Table 4. For examination scores below 50, performance values decreased and for examination scores above 50, performance value increased. There is no change for scores of 50, because this is the boundary of the limit values. Surface viewer of proposed fizzy expert system for academic performance evaluation is shown in Figure 8.

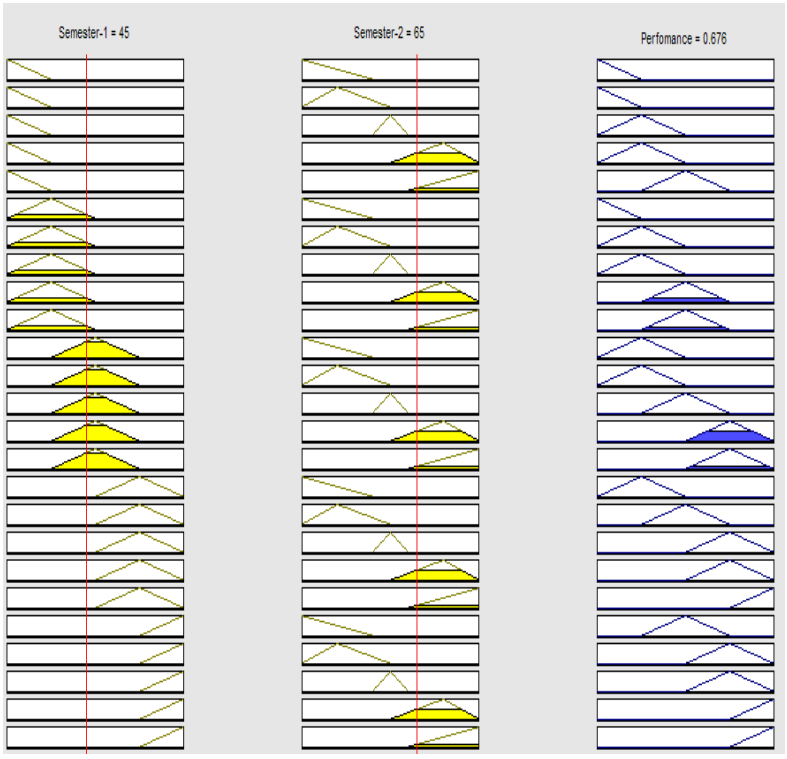

Figure 7: Active rules and performance value for examination scores of 45 and 65

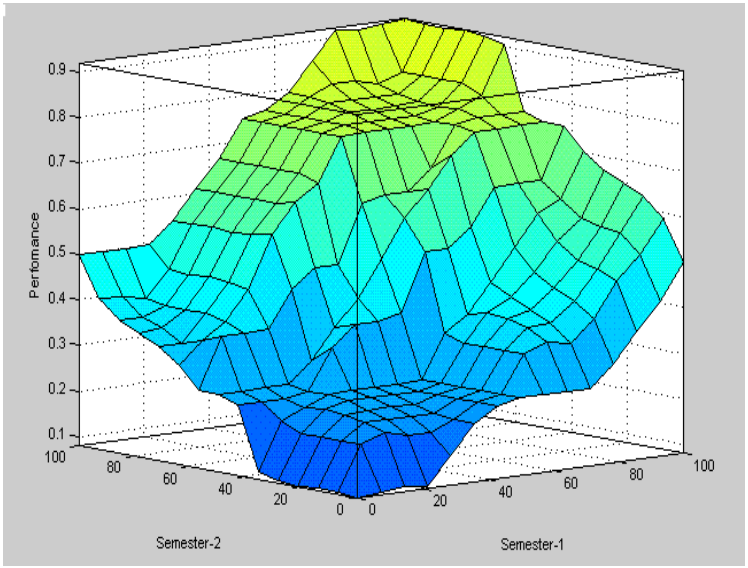

Figure 8: Surface viewer of academic performance evaluation

Table 4: Variation in performance value according to Semester Examiniation-2 (Fuzzy-2)

S. No.	Semester-1	Semester-2	Performance Value
1.	40	65	0.627
2.	20	35	0.243
3.	50	65	0.750
4.	10	20	0.203
5.	45	65	0.676
6.	34	60	0.625
7.	48	55	0.530
8.	56	90	0.758
9.	74	70	0.759
10.	45	50	0.440
11.	65	45	0.575
12.	89	100	0.908
13.	100	100	0.920
14.	65	35	0.387
15.	48	50	0.473
16.	45	55	0.490
17.	55	25	0.310
18.	84	80	0.778
19.	63	65	0.753
20.	28	30	0.241

10. DISCUSSION

Table 5 shows that comparisons between the classical method, fuzzy-1 and fuzzy-2 methods for student academic performance evaluation. Figure 9 shows that the linear relationship between the classical method and fuzzy-1. If a student is successful in the classical assessment method, they will also be successful in the fuzzy-1 scenario. Comparison of the classical method with fuzzy-2 scenario reveals differences in the performance values. For scores below 50, the performance value of fuzzy-2 is smaller than the classical method; however, for scores above 50, the performance value is larger than the classical method. For example, a student scoring 34 in semester-1 examination and 60 in semester-2 examination is unsuccessful in the classical method, but is successful in the fuzzy-2 scenario.

Table 5: Comparison of Performance Evaluation Methods

S. No.	Semester-1	Semester-2	Classical Method	Fuzzy-1	Fuzzy-2
1.	40	65	0.525	0.530	0.627
2.	20	35	0.275	0.243	0.243
3.	50	65	0.575	0.645	0.750
4.	10	20	0.150	0.203	0.203
5.	45	65	0.550	0.576	0.676
6.	34	60	0.470	0.462	0.625
7.	48	55	0.515	0.533	0.530
8.	56	90	0.73	0.759	0.758
9.	74	70	0.720	0.735	0.759
10.	45	50	0.475	0.440	0.440
11.	65	45	0.550	0.576	0.575
12.	89	100	0.945	0.908	0.908
13.	100	100	1.000	0.920	0.920
14.	65	35	0.500	0.500	0.387
15.	48	50	0.490	0.473	0.473
16.	45	55	0.500	0.500	0.490
17.	55	25	0.400	0.310	0.310
18.	84	80	0.820	0.765	0.778
19.	63	65	0.640	0.639	0.753
20.	28	30	0.290	0.310	0.241

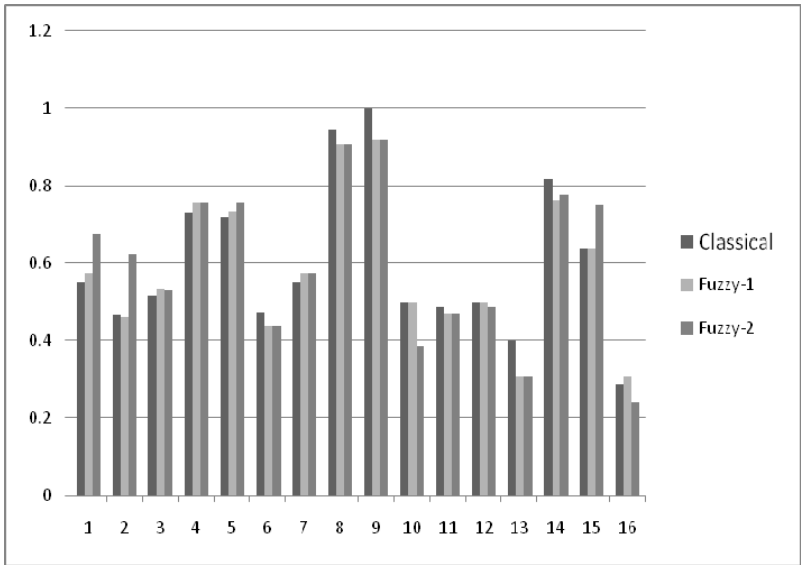

Figure 9: Comparison of Classical Method, Fuzzy-1 and Fuzzy-2 for Student Academic Performance

11. FUTURE RESEARCH

We have used soft computing techniques like Fuzzy Logic Techniques to evaluate student academic performance evaluation. It worth of future research to use combine techniques of fuzzy logic and artificial neural networks, called Neuro-Fuzzy Systems to evaluate student academic performance evaluation and also develop Intelligent Adaptive Learning Systems and Intelligent Tutoring Systems (ITS) for Internet based Education [6].

12. CONCLUSION

In this paper, we have proposed a new method for students academic performance evaluation based on fuzzy logic techniques, called Fuzzy Expert System (FES). When the results are evaluated from fuzzy expert system, a difference in outcomes is seen between the classical and proposed fuzzy logic based expert systems methods. While the classical method adheres to a constant mathematical rule, evaluation with fuzzy logic has great flexibility and reliability. In Fuzzy-1 scenario, all membership functions are same for both semester examinations, whereas in the fuzzy-2 scenario, membership functions of semester-2 examination are modified. In conclusion that student performance evaluation using fuzzy logic is suitable not only for laboratory application, but can also be used for student performance evaluation of theoretical lessons and other educational domain like e-learning and distance education provided by open University system in India.

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