Fuzzy Logic based student academic evaluation system with its general purpose software implementation in form of a website.

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***Abstract*—**In general traditional techniques for student academic evaluation are being followed at most of the educational institutions in our country. These traditional techniques mostly include percentage based evaluation or a grade point based evaluation. The area of application of fuzzy logic based system has increased exponentially since its mention by Dr. Lofti Zadeh for the first time in the year 1965. The reason for success of fuzzy systems lies in its closeness to real life situations. Keeping in mind success and usefulness of fuzzy logic based systems an attempt has been made to evaluate student academic performance with the help of a fuzzy expert system based on Mamdani technique considering attendance, internal marks and external marks as input variables for evaluation. The evaluation result is the output variable performance that is displayed in form of a numerical score associated with a linguistic descriptor. A website has also been developed so that this research does not remain limited to this paper and thus can be used by institutions to track student performance or by students themselves for self-evaluation. Although researches involving fuzzy inference systems had been done in past but their general purpose software implementation had never been done before. The website would make this research available to people with non-technical background too thus reaching maximum audience

***Keywords*—** *Academic Performance Evaluation, Fuzzy Logic, Fuzzy Inference System, Web Development*

I. INTRODUCTION

The fuzzy expert system developed here to evaluate academic performance of student is primarily developed for engineering students in India. The fuzzy model is largely influenced by the evaluation criteria followed in NIT Surat, however the beauty of fuzzy systems is that with slight variations the model can be changed according to the need of the users/evaluators. The expert system developed by author does not attempt to dismantle the evaluation criteria followed by institutions but tries to incorporate it in a fuzzy approach with modifications that are highly demanded by the students. The author being a student himself had a clear understanding about the modifications required while developing the fuzzy inference system.

The best thing about this research would be that this research does not only present its idea on paper but also implement them in form of software. The idea behind creating a website was to provide a simple interface to students, teachers and general public to reap the benefits of this work without going into much details if they do not want to. The website provides the information published in this paper in a very concise form. A proper feedback system has also been installed so that the inputs from users can be used to improve the fuzzy evaluation model further. A link to this research paper would also be provided in the website for the people interested in the fine details about the working of website and the fuzzy model used in general.

Rest of the paper is organized as follows, Section I contains an introduction to this research, Section II contains the related work to this research which discusses the same in brief, Section III discusses about the methodology involved in developing the fuzzy model and fuzzy expert system along with information about the development of website. Section IV contains the experimental results obtained when the fuzzy expert system was used to analyze the performance of 83 first year students of NIT Surat. Section V and VI concludes the research discussing future scope for the research along with some of the limitations involved in using Fuzzy Logic for evaluation of Academic Performance.

II. RELATED WORK

As mentioned above that research in this particular field of academic performance evaluation and education in general is not untouched. Researchers have touched this topic time and time again and have developed fuzzy models that perform the task of evaluation. However, every research is different in some form or another which we will be discussing in this section. [1]is a research related to evaluate the whole education system along with individual student evaluation using fuzzy approach. They proposed a model based on fuzzy logic that will not only take into account the parameters suggested by the statuary bodies to evaluate academicians but also consider the parameters from the students‟ perspective like subject knowledge, knowledge delivery, patience etc. Similarly, this research

also focused on the basic qualities of a student and evaluate the student on the basis of the exams based on university curriculum and on the basis of his/her overall development. The parameters like creativity, confidence, and discipline etc. constitute the overall development of a student. [2] Proposed a Fuzzy Expert System (FES) for student academic performance evaluation based on fuzzy logic techniques. It introduces the principles behind fuzzy logic and illustrates how these principles could be applied by educators to evaluating student academic performance. [3] has been one of my early inspiration for doing this research . This research study proposes a new fuzzy logic based performance evaluation method. In this method, they considered three parameters attendance, internal marks and external marks which are considered to evaluate students in an IT related undergraduate course. Then an expert system using fuzzy logic based on Mamdani technique has been designed. However, in this research they emphasized on 5%-10% attendance relaxation which was good but added undue weightage to attendance in their system which has been rectified in this research. [4] According to this research, Teachers do not enter the classroom as finished products. They improve with the passage of time. In this paper, they develop Educational Testing Services (ETS) that work with policy-makers and practitioners to improve teacher quality and student achievement. From their perspective, strong subject knowledge and knowledge delivery are both essential qualifications that beginning teachers must possess. It also urges all states to establish induction programs for beginning teachers, providing mentoring and support during the first years of teaching. They have put more emphasis on observing and evaluating teachers‟ teaching skills and content knowledge in their actual classrooms throughout their careers. [5] Develops a web-based information system has been implemented for engineering education. With the help of this system, they can have a comprehensive student performance evaluation based on the engagements in the laboratory activities. It only considers the practical exposure of the student in the subject concerned. This particular research did some general purpose software implementation however was based on practical exposure only. [6] Proposes a methodology using fuzzy logic to measure the quality of education by using quantitative and qualitative values with the hopes to develop criteria for the quality of education in a way closer to the realities of Latin American countries. The quality of education is measured using the parameters like the ratio of students per teacher numbers, the access that students have to technology and by appropriately spending their budget they are able to allocate to the authorities of various countries or the percentage of Gross Domestic Product (GDP) spent on education. This shows how models can change according to socio-economic conditions of a place. As a rule of thumb fuzzy models can change according to the need of its users or designers. [7,8] Reviews the various strands of research related to teacher quality including: the role of aggregate salaries, the supply of teachers with different characteristics, the relationship between teacher characteristics and student achievement, and direct estimates of the value-added of teachers. It also proposes that in order to improve the quality of teachers, their salaries and incentives play a major role. It has considered more parameters like teacher experience, teacher education and teacher test scores for evaluating teacher quality. This paper is concerned with the supply and selection of a quality teacher not with the evaluation of the currently employed teacher.

III. METHODOLOGY

As mentioned in the introduction the fuzzy inference system developed by the author closely relates to the evaluation methodology of NIT Surat or NITs in general. Here we will discuss about the details of the fuzzy models used for student academic evaluation along with their implementation in form of a website.

A. Crisp Value

The value of input variables of fuzzy models attendance, internal marks and external marks is taken in percentage form. Crisp value is the data entered by the user which goes through fuzzification process as it can not be directly used for fuzzy modelling.

Table 1. Input variables of fuzzy models.

Input variables	Description
I_1	Attendance
I_2	Internal Marks (Mid Semester Exam Marks)
I_3	External Marks (End Semester Exam Marks)

B. Number of Fuzzy Models involved in the Fuzzy Inference System and the role of Attendance input variable

The number of fuzzy models involved in developing this fuzzy inference system is two out of which only one is used at a time for actual evaluation. The attendance is not a direct input variable in any of the two fuzzy models however attendance would decide which one of the two fuzzy models would be used in evaluation. This is done in order to avoid the extra weightage given to attendance in many of the other models already developed. The change was incorporated keeping in mind the student oriented approach of this Fuzzy Inference System and at the same time the change was made in such a manner that attendance is not completely removed as an evaluation criteria but keeps it involved indirectly..

Table 2. Use of attendance in selection of Fuzzy Model

Attendance	Choice of Fuzzy Model
< 60%	No fuzzy model is chose.
60% - 75%	Fuzzy Model 1
>75%	Fuzzy Model 2

In NITs if student attendance fall less than 60% the student is awarded a “XX” grade meaning the student would not be allowed to sit in the End Semester examinations. A range of

60%-75% results in degradation of grade by one stage for example a grade of "AA" awarded for a marks range of 90%-100% is brought down to a grade "AB" awarded for a marks range of 80%-90%. The fuzzy model 1 is developed on similar lines of the degradation policy. An above 75% results in normal evaluation and correspondingly fuzzy model 2 is used for evaluation. The fuzzy models are almost similar differing only in their rule bases.

C. Fuzzification of input variables

Fuzzification of Internal marks and External marks is done by associating linguistic descriptors to each of the input variable. As discussed above attendance only provides us a choice in selection of the fuzzy model used for evaluation therefore fuzzification of attendance would not be required. Each of the descriptor is assigned either a triangular or trapezoidal membership function thus defining the overall membership function of input variables. The descriptors involved are poor, average, good, very good and excellent. Poor and Excellent have been assigned trapezoidal membership function whereas all other descriptors are provided triangular membership function. A triangular membership function is defined by a lower limit **a**, an upper limit **b**, and a value **m** also known as membership value where **a < m < b**. The equation of which is given below,

$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \frac{x-a}{m-a}, & a<x\le m \\ \frac{b-x}{b-m}, & m<x<b \\ 0, & x\ge b \end{cases}$$

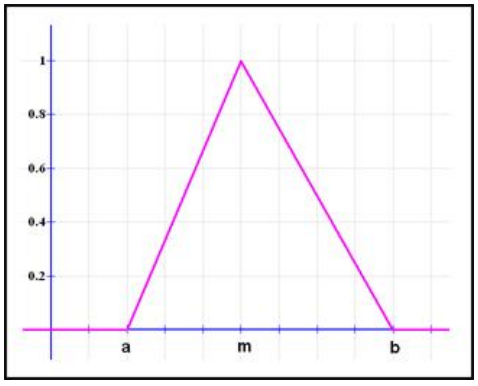

Figure 1. Graphical representation of a triangular membership function

A trapezoidal membership function is defined by a lower limit **a**, an upper limit **d**, a lower support limit **b**, and an upper support limit **c**, where **a < b < c < d**. The equation of which is given below,

$$\mu_A(x) = \begin{cases} 0, & (x < a) \text{ or } (x>d) \\ \frac{x-a}{b-a}, & a\le x\le b \\ 1, & b\le x\le c \\ \frac{d-x}{d-c}, & c\le x\le d \end{cases}$$

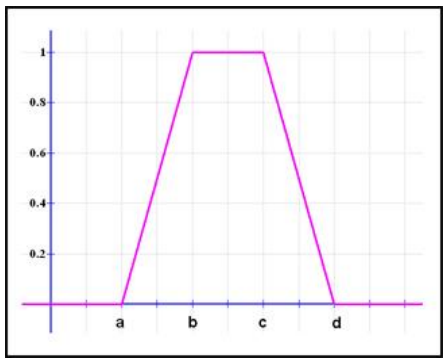

Figure 2. Graphical representation of a trapezoidal membership function

The student attendance is calculated for every subject by respective faculty by dividing the lectures attended by a student from number of working lectures. The fuzzification of Internal Marks is done by defining them in terms of linguistic variables.

Table 3. Internal marks defined in terms of linguistic variables

It should be noted that all the ranges defined in this paper

Internal Marks	Poor	Average	Good	Very Good	Excellent
I_2	< 46.66	46.66-60	60-70	70-80	> 80

are in percentage format with upper limit not included for the given linguistic variable. Membership function for input variable I_2 as simulated in Matlab R2018b's fuzzy logic designer is shown in Figure 3. ,

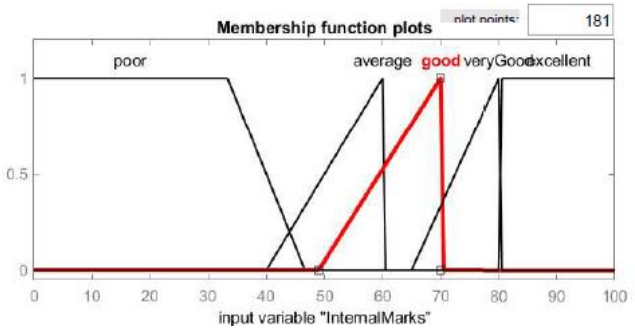

Figure 3. Membership function plot for input variable Internal Marks

The External Marks input variable is also fuzzified on similar lines to Internal Marks. However an extra weightage was given to them while developing the rule base of the Fuzzy

Expert System as they carry a larger percentage of marks in final result calculation in most of the academic systems. External Marks were defined in terms of linguistic as shown in Table 4. ,

Table 4. External marks defined in terms of linguistic variables

External Marks	Poor	Average	Good	Very Good	Excellent
I_3	<46.66	46.66-60	60-70	70-80	>80

The membership function plot for External Marks is shown now,

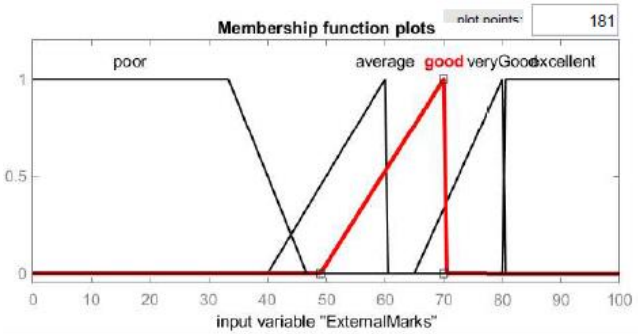

Figure 4. Membership function plot for input variable External Marks

D. Rule Base for the Fuzzy Inference System

To calculate student performance the input variables need to be evaluated in some way. The input variable are related to output variables by the help of a set of "IF-THEN"

rules which are defined by fuzzy designers to make their fuzzy models work in a certain way. Most of the changes in existing fuzzy models can be brought about by changing these rules only making fuzzy models flexible to changes.

Following figures would show the rule base involved in our fuzzy inference system.

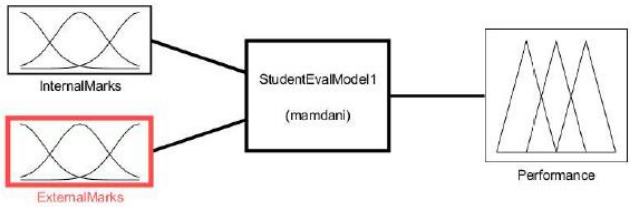

Figure 5. The Mamdani based Fuzzy Inference System having Internal and External Marks as input and Performance as output.

	INTERNA	EXTERNA	PERFORM
1	POOR	POOR	POOR
2	POOR	AVERAGE	POOR
3	POOR	GOOD	POOR
4	POOR	VERY GOOD	AVERAGE
5	POOR	EXCELLENT	AVERAGE
6	AVERAGE	POOR	POOR
7	AVERAGE	AVERAGE	POOR
8	AVERAGE	GOOD	AVERAGE
9	AVERAGE	VERY GOOD	AVERAGE
10	AVERAGE	EXCELLENT	GOOD
11	GOOD	POOR	POOR
12	GOOD	AVERAGE	POOR
13	GOOD	GOOD	AVERAGE
14	GOOD	VERY GOOD	GOOD
15	GOOD	EXCELLENT	GOOD
16	VERY GOOD	POOR	POOR
17	VERY GOOD	AVERAGE	AVERAGE
18	VERY GOOD	GOOD	GOOD
19	VERY GOOD	VERY GOOD	GOOD
20	VERY GOOD	EXCELLENT	VERY GOOD
21	EXCELLENT	POOR	POOR
22	EXCELLENT	AVERAGE	AVERAGE
23	EXCELLENT	GOOD	GOOD
24	EXCELLENT	VERY GOOD	GOOD
25	EXCELLENT	EXCELLENT	VERY GOOD

Figure 6. Rule Base for fuzzy model corresponding to an attendance range of 60%-75%.

	INTERNA	EXTERNA	PERFORM
1	POOR	POOR	POOR
2	POOR	AVERAGE	AVERAGE
3	POOR	GOOD	AVERAGE
4	POOR	VERY GOOD	GOOD
5	POOR	EXCELLENT	GOOD
6	AVERAGE	POOR	POOR
7	AVERAGE	AVERAGE	AVERAGE
8	AVERAGE	GOOD	GOOD
9	AVERAGE	VERY GOOD	GOOD
10	AVERAGE	EXCELLENT	VERY GOOD
11	GOOD	POOR	AVERAGE
12	GOOD	AVERAGE	AVERAGE
13	GOOD	GOOD	GOOD
14	GOOD	VERY GOOD	VERY GOOD
15	GOOD	EXCELLENT	VERY GOOD
16	VERY GOOD	POOR	AVERAGE
17	VERY GOOD	AVERAGE	GOOD
18	VERY GOOD	GOOD	VERY GOOD
19	VERY GOOD	VERY GOOD	VERY GOOD
20	VERY GOOD	EXCELLENT	EXCELLENT
21	EXCELLENT	POOR	AVERAGE
22	EXCELLENT	AVERAGE	GOOD
23	EXCELLENT	GOOD	VERY GOOD
24	EXCELLENT	VERY GOOD	VERY GOOD
25	EXCELLENT	EXCELLENT	EXCELLENT

Figure 7. Rule Base for fuzzy model corresponding to an attendance range of 75%-100%

The rule base for any fuzzy inference system is defined both logically and mathematically. The author has used statistical methods while defining and implementing the rule base in Matlab giving extra weightage to External marks in the process.

E. Defuzzification of output variable Performance

If the antecedent of a rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the rule antecedent. The fuzzy operator used here is AND whose function is defined as minimum value function in Matlab. The defuzzification method used is the centroid defuzzification method. [9] This procedure (also called center

of area, center of gravity) is the most prevalent and physically appealing of all the defuzzification methods it is given by the algebraic expression

$$z^* = \frac{\int \mu_{\tilde{C}}(z) \cdot z \, dz}{\int \mu_{\tilde{C}}(z) \, dz}$$

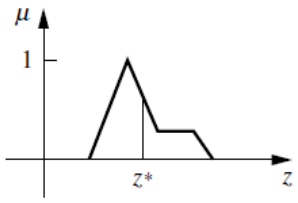

Figure 8. Centroid Defuzzification method

Here, z^* is the defuzzified value which corresponds to Performance in our case. The output variable Performance is defined in terms of similar linguistic variables as used in case of input variables.

Table 5. Performance defined in terms of linguistic variables

Performance	Poor	Average	Good	Very Good	Excellent
z^*	0-46.66	46.66-60	60-70	70-80	>80

The membership function of Performance is similar to Internal or External marks so it would not be shown again however a Surface Viewer of Fuzzy Expert System with input variables is shown in the next figure, the surface viewer is generated by Matlab.

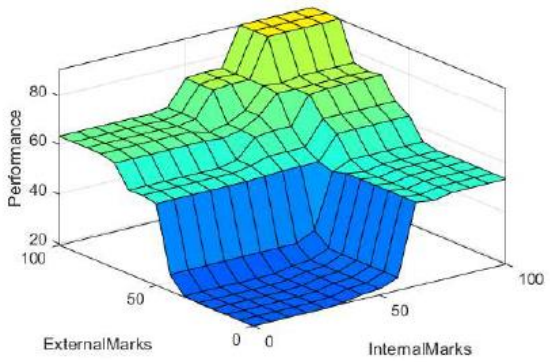

Figure 9. Surface Viewer for Fuzzy Model corresponding to an Attendance range of 75%-100%

F. Website

To put everything discussed in this research in action a website was developed by the author. The frontend of the website is developed using frontend languages HTML, CSS and JavaScript whereas the backend uses JSP (Java Server Pages) which facilitates the use of Java libraries. All the fuzzy modelling for the research was done in Matlab however due to the complexity involved in running Matlab programs on Server Side an alternative was used. This alternative being [10] jFuzzyLogic: an open source fuzzy logic library implementing industry standards to simplify fuzzy systems developments. It is a fuzzy logic package written in Java. It implements Fuzzy control language (FCL) specification IEC 61131 part 7, as well as a complete library that will greatly simplify your fuzzy logic development or research work. Most of the Matlab based implementation that involves defining of membership functions, Rule base, Defuzzification method etc. can be specified in the FCL file which is read by the jFuzzyLogic library internal methods to produce a FIS Model. Further passing the user input of attendance, Internal Marks and External Marks to some other functions of the jFuzzyLogic Library the output is easily obtained which is then printed on the user's side completing the functioning of the website.

```
FUNCTION_BLOCK Evaluation
VAR_INPUT
    InternalMarks : REAL;
    ExternalMarks : REAL;
END_VAR
VAR_OUTPUT
    Performance : REAL;
END_VAR
FUZZIFY InternalMarks
    TERM poor := (0,0) (0,1) (33.33,1) (46.66,0)  ;
    TERM average := (40, 0) (60,1) (60,0) ;
    TERM good := (49,0) (70,1) (70,0);
    TERM very_good := (65,0) (80,1) (80,0);
    TERM excellent := (80.1,0) (80.1,1) (101,1) (101,0);
END_FUZZIFY
FUZZIFY ExternalMarks
    TERM poor := (0,0) (0,1) (33.33,1) (46.66,0)  ;
    TERM average := (40, 0) (60,1) (60,0) ;
    TERM good := (49,0) (70,1) (70,0);
    TERM very_good := (65,0) (80,1) (80,0);
    TERM excellent := (80.1,0) (80.1,1) (101,1) (101,0);
END_FUZZIFY
DEFUZZIFY Performance
    TERM poor := (0,0) (0,1) (33.33,1) (46.66,0)  ;
    TERM average := (40, 0) (60,1) (60,0) ;
    TERM good := (49,0) (70,1) (70,0);
    TERM very_good := (65,0) (80,1) (80,0);
    TERM excellent := (80.1,0) (80.1,1) (101,1) (101,0);
    METHOD : COG;
    DEFAULT := 0;
END_DEFUZZIFY
RULEBLOCK No1
    AND : MIN;
    ACT : MIN;
    ACCU : MAX;
    RULE 1 : IF InternalMarks IS poor and ExternalMarks IS poor THEN Performance is poor ;
    RULE 2 : IF InternalMarks IS poor and ExternalMarks IS average THEN Performance is average ;
    RULE 3 : IF InternalMarks IS poor and ExternalMarks IS good THEN Performance is average ;
    RULE 4 : IF InternalMarks IS poor and ExternalMarks IS very_good THEN Performance is good ;
    RULE 5 : IF InternalMarks IS poor and ExternalMarks IS excellent THEN Performance is good ;
```

Figure 10. A glimpse of a FCL file used in development of website

IV. EXPERIMENTAL RESULTS

The fuzzy expert system was used to evaluate the performance of 82 first year B. Tech students for the subject "Basics of Electronics Engineering" in a given semester. The 82 students are part of one batch out of five batches that took the exam.

Table 6. Grades awarded in the conventional system

Grade	Value ranges on a scale of 0-10
AA	9-10
AB	8-9
BB	7-8

BC	6-7
CC	5-6
CD	4-5
DD	3-4
FF	0
XX	Unsatisfactory Attendance

The table above gives a brief about the grades involved in the conventional system and their numerical significance. Based on the above table and Performance values defined in Table 5 a logical analogy can be developed between the performance linguistic variable and grades involved in the academic system thus allowing us to compare the conventional result with fuzzy expert system based result and is shown in the first two columns of Table 7. By Conventional result author means the final grade awarded by the institution to the student in the given subject.

Table 7. Comparison of Fuzzy Expert System with Conventional result

Grade	Performance	No. of students in given range according to conventional result	No. of students in given range according to Fuzzy Expert System
AA	Excellent	10	8
AB			
BB	Very Good	18	21
BC	Good	25	19
CC	Average	18	24
CD			
DD	Poor	11	10
FF			

V. CONCLUSION

Table 7 shows the close relation between the result obtained by fuzzy expert system and conventional result. As in any academic system the number of students scoring the top grades is limited which has been well followed in the fuzzy system as well. For rest of the grades too the fuzzy expert system imitates the student distribution as provided by the conventional result. The difference in frequency of students in column three and four of Table 7 is minimum one and maximum six which can be accepted considering the sample taken was for only one batch out of all five batches. The frequency of students in column four of Table 7 was calculated using website developed for this research. A limitation to this approach is however the relative grading system followed in NITs and some other colleges. A difficult examination paper would lead to fall in the average marks scored by students. In such a case the topper student who might have scored only 60% marks would get an excellent grade of AA or AB but our fuzzy expert system would treat the performance as good or average. This was one limitation and there might be some more. No system is perfect but constant improvement can make it near perfect for example, adding an input parameter of paper difficulty might solve the above problem. This research mainly focused on to show the correctness and closeness of fuzzy evaluation system to the conventional techniques of academic performance evaluation along with developing a software tool for the use of all.

VI. WEBSITE AND FUTURE SCOPE

Although mentioned in the title of the paper the website has not been discussed in great detail in the paper. The author particularly believes that action speaks louder than words hence there is no better way for readers to experience the website themselves and give a feedback to the author resulting in the improvement of this research that has been directly implemented in the form of a website. With this website also lies the future scope of this research, if liked by users and authorities involved in academic performance evaluation this fuzzy based method can be used by them instead of traditional techniques. Here I invite you to visit the website here and contribute by constructive criticism.

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