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A Fuzzy Approach to Educational Grading Systems "Fuzzy Logic Based Grade Card"

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***Abstract:** This study aims at developing a fuzzy approach for the educational grading systems. Through this study a fuzzy logic-based grading card is suggested. The grading system based on crisp approach just deals with numbers. Fuzziness, being an important property of language, motivates us to work and study in this fuzzy environment. Before discussing the actual grade card some introduction about the key concepts is given for the readers. We have also analyzed the difference in grading and evaluating systems followed from the decades and the new fuzzy logic-based evaluation system. It also includes connectivity levels, advantages, and disadvantages between both evolution methods. The future scope of the fuzzy grading system is also discussed. The report will conclude with the answer to the question, "Is a fuzzy logic- based grade card worth for the educational grading systems?". Moreover, towards the end, suggestions will be provided on how to bring more of these fuzzy approaches into education systems.*

***Index Terms:** Fuzzy logic, Fuzzy logic-based grading card, Mamdani fuzzy inference, Logical reasoning*

I. INTRODUCTION

A. History

If we look around us, there are so many processes going on. There are so many things present around us. We use our sensors to observe our surroundings. We see things, we feel things, and most importantly we make decisions based on our observations. But as every decision requires some rigid base to dwell on our ideas and thought processes, we must get numerical information for everything which we observe. But what if everything is not that clear? There are situations when we are in a bit of darkness and can't figure out what exactly is happening. Then how should we take the decisions? For example, if there is a cup of tea in front of us, what can we say about its temperature? Is it hot? Is it cold? Or something in between this? Obviously, we all are not the same. That means our answers would not be the same. So how to deal with these situations? How to take decisions in these situations? The answer to all the above questions was given by Lotfi Zadeh, who was a scientist in the University of California at Berkeley. In the 1960s he was dealing with computations involved in Natural Language Processing.

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Natural Language, similar to our day-to-day activities, is not easy to convert everything into absolute values [1]. At that time only Boolean and crisp systems were used to deal with logic. But the biggest problem of these systems is the conversion of everything into absolute values. Lotfi Zadeh was also dealing with the same problem, then he came up with a research paper titled "Fuzzy Sets" in 1965 and established the foundations of concepts of fuzzy sets, fuzzy logic, and fuzzy environment.

B. Crisp Logic

Crisp is a term very related to precision and exactness. The Crisp system is also known as the Boolean system. It deals with values with a strict boundary i.e., true, or false. The value should either be true or false to be called a crisp value. It cannot contain any in-between values. In the Boolean system truth value, one represents the absolute truth value, and zero represents the absolute false value. i.e., one is true, and zero is false [2]. However, in the case of a fuzzy logic system, we have intermediate values, which are partially true and partially false. In the Boolean system, an element is either the member of a set or not.

Let us take a use case related to the education system. If a true or false statement is given to someone, then the statement is either true or false. Here, we can easily give one or zero value to each of those statements. But when we write any answer of disciplines like English or Biology where we must explain something, then the paragraph which we write is not totally correct or totally wrong. Then the Boolean system of evaluation is not appropriate. Even in disciplines like mathematics, we have step marking and partial marking.

C. Fuzzy Logic

Fuzzy logic is an extension of the Boolean system or the crisp system. Fuzzy logic is a new and innovative approach to solve logic-based problems. In the Boolean system, we only use discrete values for logic, one and zero. Whereas, in a fuzzy system the value is a continuous variable and can take any value between zero and one [3]. Here, every element is present in the fuzzy set by a degree of truth. Fuzzy logic provides us with a lot of flexibility for reasoning. Fuzzy logic is broadly studied under soft computing, and artificial intelligence. A simple conclusion can also be made here that fuzzy logic is a superset of Boolean logic, or Boolean logic is a special case of fuzzy logic. Let us take the example of a self-driving car. Let the speed of that car be monitored by an AI agent, which is based on the Boolean system. Then the speed of the car would be divided into two categories, fast and slow by a particular value of speedometer, say 50 kmph.

If the speed of the car is less than 50 km/hr., the car would accelerate. If it is more than 50 kmph, the agent would press the brake. Now what if the speed of the car is 49 km/hr.? The agent senses that the speed is less and presses the accelerator. The speed reaches 51 km/hr., the agent presses brakes. Hence, the car would just oscillate between stopping and accelerating. But using fuzzy logic here gives us a lot of flexibility at edges. We can instruct the agent that his speed is between 45 km/hr. to 55 km/hr. then it must behave in some other way.

D. A Simple Example

Now let's consider an example to show how a Boolean system truth value works and how a fuzzy logic system works. Let us take a question, Is tea hot? In the Boolean system having crisp values, we can see two solutions, YES or NO, but in a fuzzy logic system with fuzzy values, we can see that there are many solutions - Extremely hot, very hot, cold, and extremely cold. So, we can say that in a Boolean system having crisp values, we only have the absolute false value and the absolute true value but in a fuzzy logic system, we have these partially true and partially false values as we can see extremely hot is somewhat close to absolute truth so we can say that they are partially true similarly extremely cold is somewhat similar to absolutely false value so we can say that is partially false. This is the basic difference between fuzzy logic systems and crisp systems.

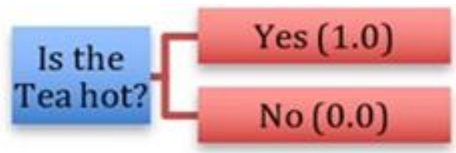

Figure 1: Crisp Values

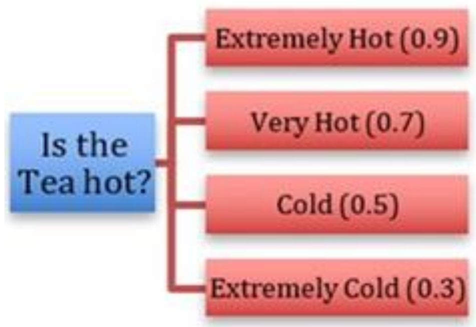

Figure 2: Fuzzy Values

E. Membership Functions

Now we will discuss membership functions. Membership functions were first introduced in 1965 by Lofti Zadeh in his first research paper 'fuzzy sets'. They characterize fuzziness, i.e., all the information in a fuzzy set, whether the elements in the fuzzy set are discrete or continuous and represent the degree of truth in a fuzzy logic system. In the previous example for a Boolean system having crisp values, for the solution NO, this represents the absolute false value; therefore, the membership value over here would be 0 whereas, in the case of a true value, the membership value would be 1. Fuzzy logic is somewhat different since we are dealing with partially true and partially false values in the case of fuzzy logic. We have membership values as 0.9, 0.7, 0.5, and 0.3. These values are assigned to the degree of truth in the fuzzy system. As we can see, extremely hot is more like the absolute true value, so we have assigned it a value of 0.9, close to 1. Similarly, extremely cold is like the absolute false value; therefore, we have assigned the value of 0.3, close to 0. So, this is how the fuzzy logic systems take up partial values, and each partial value will have a membership value assigned to it. So, we can say that membership functions govern fuzzy logic systems.

II. WHY FUZZY LOGIC BASED GRADE CARD?

For our research, we chose students as our target audience. The students' domain provides us an opportunity to explore many exciting applications of fuzzy logic. This research can help in improving the quality of the education system. The academic performance of students generally represents the basis of any education system. Therefore, this research re- volves around developing a Grade Card for students using fuzzy logic. This grade card would act as a framework for students' academic grading. It can quantify linguistic opinions. The research will be a help for scenarios where the fuzzy approach is better than traditional grading systems.

Let us take a use case to understand more. Whenever any student submits any project or assignment for checking, he/she generally has to accompany it with some presentation. Let us assume the presentations are not recorded, the grading is relative, and a group of instructors evaluate the presentation. In one go, instructors give linguistic opinions like good, bad, excellent, or satisfying, etc. Later, they discuss and grade the project, which may be time-consuming. It may also lead to a debate among instructors. Also, may cause certain attributes to be unconsidered. Hence, we need some fuzzy logic-based grading system to convert those on-the-spot linguistic opinions to final grading.

III. FUZZY LOGIC BASED GRADE CARD

Let us now make an actual fuzzy based grade card. The card would be used to evaluate the projects of university students. Let us consider such a scenario. Suppose we evaluate students in the mathematics department. Every student is asked to do a project. The project is about making software for some use case of mathematics. The project would be graded on some parameters. Marks obtained by a student in all those chosen parameters would be summed up, for final grading of his project. Let us consider 10 such parameters.

A. The list of parameters:

1. **Report**: The project must be submitted with a report. The report will contain all the information about the use case, about the software, how the work was done, and all other relevant information.
2. **Presentation**: It includes the PowerPoint slides and the verbal presentation given by the student. During the presen- tation the student would explain all the things which he/she did to complete the project. It also includes the question-and- answer session conducted by the evaluating panel.

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3. **Original**: All the work which a student is submitting must be plagiarism free. The report and code of the software must be his/her own. The panel may ask students to submit a plagiarism report along with the project.
4. **Proof**: As the project is based on some of the use cases of mathematics. Some theorems, corollaries, must be used in the project. So, is the proof and justification of all the mathematical parts present in the report or not and are they correct or not.
5. **Idea**: The idea of a use case and making of that software must be new and novel. If the idea is taken from somewhere else, then the uniqueness and originality of the student is not reflected by that project.
6. **Code**: The code submitted by the student must be properly written and indented. Whether the student used the programming language, which was given to him or some, he used some other language of his choice.
7. **Frontend**: The user interference part of the software must be attractive and usable. It must be easily understandable. All the functions of the front end are working correctly or not. Are they doing what they are asked to do or not, if not then to what extent is the error?
8. **Backend**: The backend of the software is again equally important. It must contain all the features which were asked for by the panel. The panel may ask students to explain some portion of the backed code, or some function explanation.
9. **Performance**: This parameter deals with the performance of the software. Is the software doing what it is asked to do? What is the accuracy of it, and is the backend and frontend compiled properly or not?
10. **Research**: For doing the project, the student must do some research work. It includes the literature review, going through the notes of the relevant courses taught. If required, the student can also refer to some reference books of that use case or the mathematical part.

Now suppose the total marks of the project are 100. Each parameter of the project is of 10 marks. After checking a student's project, the panel has to give marks for each of those parameters.

Let us first consider the presentation parameter. If the panel evaluates the project according to the traditional evaluation, then obviously we are dealing in a crisp or Boolean system. Recall that crisp or Boolean system is all about exactness. Here, when a student would be giving the presentation then the panel has to instantly give marks from 0 to 10. But this is not easy as by seeing a presentation only once, one cannot give exact and accurate marks which the student deserves. The solution to such a problem can be to group or cluster some of the marks from the scale of 0 to 10 into some linguistic opinions. Now one approach to do so can be to assign some linguistic opinion to each of those 11 digits. Still, the panel has to give on the spot exact linguistics for the presentation. Moreover, this is not a fuzzy approach as here we have just represented all those 11 digits with some English words. Instead, we have made it difficult to evaluate, as first the panel has to give some linguistic opinion and then the conversion of it to the marks. Another approach would be to use a set of digits for one linguistic opinion. So, let us first assign some linguistic opinions to each of those parameters. For simplicity we can consider that all those parameters have the same linguistic opinion but in general, it is not true so we will consider different linguistic opinions for different parameters.

1) **Report and Presentation:**
   a. Excellent
   b. Very Good
   c. Good
   d. Fair
   e. Bad
   f. Very Bad
2) **Original and Performance:**
   a. Very High
   b. High
   c. Normal
   d. Fair
   e. Low
   f. Very Low
3) **Proof and Code:**
   a. Perfect
   b. Nice
   c. Satisfactory
   d. Average
   e. Ambiguous
   f. Nil
4) **Idea and Research:**
   a. Best
   b. Very Good
   c. Good
   d. Normal
   e. Fair
   f. Bad
5) **Frontend and Backend:**
   a. Excellent
   b. Very Good
   c. Good
   d. Not Good
   e. Fair
   f. Bad

Now let's say from 0 to 10 marks, excellent linguistic value is assigned for 8, 9, and 10 marks. If a student gets an excellent opinion for his presentation, then obviously his marks would be 8, 9, or 10 only. So, the marks below 8 are now removed from the list. However, it has two problems. First problem is that it is still an exact approach, the marks of the student can be from 8, 9, and 10 only, and not from the remaining ones. Obviously, this makes it easier for the panel to give excellent results at this time and they are not worried about the exact marks. The second problem is that suppose four students get an excellent opinion for the presentation. Then what about their exact marks? Are all of them getting 8 or 9 or 10? One solution for this problem can be to ask for the membership function (mgf) from the panel for all the linguistic opinions which they are giving on the spot. Now if someone gives 0.8 as a membership function for excellent then what would be the process of reaching to the exact marks? Here, one can define some threshold or cut off for the three digits. Like:

$$Marks = \begin{cases} 10, & 1.0 \le mgf \le 0.8 \\ 9, & 0.8 \le mgf \le 0.4 \\ 8, & 0.4 \le mgf \le 0.0 \end{cases}$$

But this approach again has three problems:

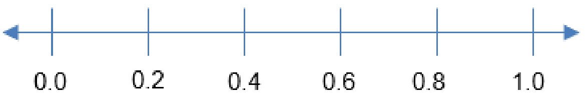
1. We have made it difficult for the panel to give marks. The panel has to remember all the cutoffs for all the linguistic values.
2. By including cut-offs for all the marks, we have again made it an exact approach. Hence, we still need to give a fuzzy approach to this evaluation system.
3. Our aim was only to ask for the linguistic opinion and not the membership function.

The solution to this problem can be to give a specific value to the membership function for excellent linguistics. But again, it is a problem that all the members of the panel would not be giving the same value for the membership function. Also, to reach the exact marks we again need to give some cut off for the marks, and we are again not making it a fuzzy approach.

The solution to this can be to give a group of values for the membership function.

Excellent **=** *f (Excellent, Very Good, Good, Fair, Bad, Very Bad)*

Now the excellent linguistic is not only excellent, but it also has other linguistic values, with some proportion. Hence, now we can say we are moving toward the fuzzy approach. As a value for membership function can only be between 0 to 1 and we have six linguistic values. So let us divide the interval by a difference of 0.2. Therefore, we will be getting 5 intervals and 6 points.



Now let us define a proper membership function for excellent.

$$Excellent = \frac{1.0}{Excellent} + \frac{0.8}{Very\ Good} + \frac{0.6}{Good} + \frac{0.4}{Fair} + \frac{0.2}{Bad} + \frac{0.0}{Very\ Bad}$$

Here excellent has 1.0 of excellent, 0.8 of very good, 0.6 of good, 0.4 of fair, 0.2 of bad, and 0.0 of very bad. As there are 10 such parameters for evaluating the project, and all of them do not have the same linguistics. For using hamming distance and Mamdani fuzzy inference, we need the same linguistic values. So let us denote this linguistics with some digits. For presentation parameter we have,

$$Let, \quad Excellent = 1, Very\ Good = 2, Good = 3, Fair = 4, Bad = 5, Very\ Bad = 6$$

$$\Rightarrow Excellent = \frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Now we require the ideal performance of a student in the project for the final grading. There we would be giving the highest possible linguistic value to each of the parameters.

1. Report and **Presentation (Excellent):**

$$\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

2. Original and **Performance (Very High):**

$$\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

3. Proof and **Code (Perfect):**

$$\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

4. Idea and **Research (Best):**

$$\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

5. Frontend and **Backend (Excellent):**

$$\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Now we would be using the **hamming distance** to compare the performance of each student from the ideal performance. Let us first do this for the presentation parameter.

Excellent: $\frac{1.0}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$

Very Good: $\frac{0.8}{1} + \frac{1.0}{2} + \frac{0.8}{3} + \frac{0.6}{4} + \frac{0.4}{5} + \frac{0.2}{6}$

Good: $\frac{0.6}{1} + \frac{0.8}{2} + \frac{1.0}{3} + \frac{0.8}{4} + \frac{0.6}{5} + \frac{0.4}{6}$

Fair: $\frac{0.4}{1} + \frac{0.6}{2} + \frac{0.8}{3} + \frac{1.0}{4} + \frac{0.8}{5} + \frac{0.6}{6}$

Bad: $\frac{0.2}{1} + \frac{0.4}{2} + \frac{0.6}{3} + \frac{0.8}{4} + \frac{1.0}{5} + \frac{0.8}{6}$

Very Bad: $\frac{0.0}{1} + \frac{0.2}{2} + \frac{0.4}{3} + \frac{0.6}{4} + \frac{0.8}{5} + \frac{1.0}{6}$

Hamming distance of all linguistic values from excellent are (refer appendix for calculations):

1. **Excellent (Ex):** 0.0 units
2. **Very Good (A+):** 1.2 units
3. **Good (A):** 2.0 units
4. **Fair (B+):** 2.8 units
5. **Bad (B):** 3.2 units
6. **Very Bad (C):** 3.6 units

To find the final grades, we need to multiply these distances by 6, as there are 6 such logistic values. Then we would get 0.0, 7.2, 11.99, 16.8, 19.2, and 21.59 units of distances respectively. The grades which are used here are just some random grades, one can always define grades according to his or her own requirements. Here, the A+ grade is best and C grade is worst Therefore, now the grades are ready with us,

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$$Grade = \begin{cases} A+, & Total\ Marks < 7.2 \\ A, & 7.20 \leq Total\ Marks < 11.99 \\ B+, & 11.99 \leq Total\ Marks < 19.80 \\ B, & 16.80 \leq Total\ Marks < 19.20 \\ C+, & 19.20 \leq Total\ Marks < 21.59 \\ C, & 21.59 \leq Total\ Marks \end{cases}$$

From the hamming distances we can say there is sufficient gap between each of these linguistics, and excellent and bad are at farthest distance from each other. Now let us properly define the membership function for each of the parameters.

1. **Report** and **Presentation:**
   a. **Excellent:** $\frac{1.0}{1}+\frac{0.8}{2}+\frac{0.6}{3}+\frac{0.4}{4}+\frac{0.2}{5}+\frac{0.0}{6}$
   b. **Very Good:** $\frac{0.8}{1}+\frac{1.0}{2}+\frac{0.8}{3}+\frac{0.6}{4}+\frac{0.4}{5}+\frac{0.2}{6}$
   c. **Good:** $\frac{0.6}{1}+\frac{0.8}{2}+\frac{1.0}{3}+\frac{0.8}{4}+\frac{0.6}{5}+\frac{0.4}{6}$
   d. **Fair:** $\frac{0.4}{1}+\frac{0.6}{2}+\frac{0.8}{3}+\frac{1.0}{4}+\frac{0.8}{5}+\frac{0.6}{6}$
   e. **Bad:** $\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.6}{3}+\frac{0.8}{4}+\frac{1.0}{5}+\frac{0.8}{6}$
   f. **Very Bad:** $\frac{0.0}{1}+\frac{0.2}{2}+\frac{0.4}{3}+\frac{0.6}{4}+\frac{0.8}{5}+\frac{1.0}{6}$
2. **Original** and **Performance:**
   a. **Very High:** $\frac{1.0}{1}+\frac{0.8}{2}+\frac{0.6}{3}+\frac{0.4}{4}+\frac{0.2}{5}+\frac{0.0}{6}$
   b. **High:** $\frac{0.8}{1}+\frac{1.0}{2}+\frac{0.8}{3}+\frac{0.6}{4}+\frac{0.4}{5}+\frac{0.2}{6}$
   c. **Normal:** $\frac{0.6}{1}+\frac{0.8}{2}+\frac{1.0}{3}+\frac{0.8}{4}+\frac{0.6}{5}+\frac{0.4}{6}$
   d. **Fair:** $\frac{0.4}{1}+\frac{0.6}{2}+\frac{0.8}{3}+\frac{1.0}{4}+\frac{0.8}{5}+\frac{0.6}{6}$
   e. **Low:** $\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.6}{3}+\frac{0.8}{4}+\frac{1.0}{5}+\frac{0.8}{6}$
   f. **Very Low:** $\frac{0.0}{1}+\frac{0.2}{2}+\frac{0.4}{3}+\frac{0.6}{4}+\frac{0.8}{5}+\frac{1.0}{6}$
3. **Proof** and **Code:**
   a. **Perfect:** $\frac{1.0}{1}+\frac{0.8}{2}+\frac{0.6}{3}+\frac{0.4}{4}+\frac{0.2}{5}+\frac{0.0}{6}$
   b. **Nice:** $\frac{0.8}{1}+\frac{1.0}{2}+\frac{0.8}{3}+\frac{0.6}{4}+\frac{0.4}{5}+\frac{0.2}{6}$
   c. **Satisfactory:** $\frac{0.6}{1}+\frac{0.8}{2}+\frac{1.0}{3}+\frac{0.8}{4}+\frac{0.6}{5}+\frac{0.4}{6}$
   d. **Average:** $\frac{0.4}{1}+\frac{0.6}{2}+\frac{0.8}{3}+\frac{1.0}{4}+\frac{0.8}{5}+\frac{0.6}{6}$
   e. **Ambiguous:** $\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.6}{3}+\frac{0.8}{4}+\frac{1.0}{5}+\frac{0.8}{6}$
   f. **Nil:** $\frac{0.0}{1}+\frac{0.2}{2}+\frac{0.4}{3}+\frac{0.6}{4}+\frac{0.8}{5}+\frac{1.0}{6}$
4. **Idea** and **Research:**
   a. **Best:** $\frac{1.0}{1}+\frac{0.8}{2}+\frac{0.6}{3}+\frac{0.4}{4}+\frac{0.2}{5}+\frac{0.0}{6}$
   b. **Very Good:** $\frac{0.8}{1}+\frac{1.0}{2}+\frac{0.8}{3}+\frac{0.6}{4}+\frac{0.4}{5}+\frac{0.2}{6}$
   c. **Good:** $\frac{0.6}{1}+\frac{0.8}{2}+\frac{1.0}{3}+\frac{0.8}{4}+\frac{0.6}{5}+\frac{0.4}{6}$
   d. **Normal:** $\frac{0.4}{1}+\frac{0.6}{2}+\frac{0.8}{3}+\frac{1.0}{4}+\frac{0.8}{5}+\frac{0.6}{6}$
   e. **Fair:** $\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.6}{3}+\frac{0.8}{4}+\frac{1.0}{5}+\frac{0.8}{6}$
   f. **Bad:** $\frac{0.0}{1}+\frac{0.2}{2}+\frac{0.4}{3}+\frac{0.6}{4}+\frac{0.8}{5}+\frac{1.0}{6}$
5. **Frontend** and **Backend:**
   a. **Excellent:** $\frac{1.0}{1}+\frac{0.8}{2}+\frac{0.6}{3}+\frac{0.4}{4}+\frac{0.2}{5}+\frac{0.0}{6}$
   b. **Very Good:** $\frac{0.8}{1}+\frac{1.0}{2}+\frac{0.8}{3}+\frac{0.6}{4}+\frac{0.4}{5}+\frac{0.2}{6}$
   c. **Good:** $\frac{0.6}{1}+\frac{0.8}{2}+\frac{1.0}{3}+\frac{0.8}{4}+\frac{0.6}{5}+\frac{0.4}{6}$
   d. **Not Good:** $\frac{0.4}{1}+\frac{0.6}{2}+\frac{0.8}{3}+\frac{1.0}{4}+\frac{0.8}{5}+\frac{0.6}{6}$
   e. **Fair:** $\frac{0.2}{1}+\frac{0.4}{2}+\frac{0.6}{3}+\frac{0.8}{4}+\frac{1.0}{5}+\frac{0.8}{6}$
   f. **Bad:** $\frac{0.0}{1}+\frac{0.2}{2}+\frac{0.4}{3}+\frac{0.6}{4}+\frac{0.8}{5}+\frac{1.0}{6}$

Therefore, these 10 parameters along with their linguistic values and membership functions constitute our required fuzzy logic based grade card. Further, the grade function can be used to assign the final grades.

IV. AN EXAMPLE FOR DEMONSTRATION

Let us take an example to understand the working of the fuzzy based grade card. Let us consider a panel of five examiners, who have to evaluate four students for the project. For simplicity we will consider two parameters for evaluation namely, **performance** of the software prepared and the **idea** behind the software and the use case.

Performance				
	Student-1	*Student-2*	*Student-3*	*Student-4*
Examiner-1	Very High	Normal	Very High	Normal
Examiner-2	High	High	Very High	Fair
Examiner-3	Very High	High	Low	High
Examiner-4	Very High	Normal	Very High	Very High
Examiner-5	High	Very High	Very High	Fair

Idea				
	Student-1	*Student-2*	*Student-3*	*Student-4*
Examiner-1	Very Good	Good	Best	Good
Examiner-2	Best	Normal	Normal	Very Good
Examiner-3	Best	Normal	Very Good	Good
Examiner-4	Very Good	Good	Good	Bad
Examiner-5	Very Good	Normal	Fair	Normal

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Now we will be using the **Mamdani Fuzzy Inference** rule to find the resultant value. For **Performance** we have (refer appendix for calculations),

Student-1: Very High **AND** High **AND** Very High **AND** Very High **AND** High

$$= \frac{0.8}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Student-2: Normal **AND** High **AND** High **AND** Normal **AND** Very High

$$= \frac{0.6}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Student-3: Very High **AND** Very High **AND** Low **AND** Very High **AND** Very High

$$= \frac{0.2}{1} + \frac{0.4}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Student-4: Normal **AND** Fair **AND** High **AND** Very High **AND** Fair

$$= \frac{0.4}{1} + \frac{0.6}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

For **Idea** we have (refer appendix for calculations),

Student-1: Very Good **AND** Best **AND** Best **AND** Very Good **AND** Very Good

$$= \frac{0.8}{1} + \frac{0.8}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Student-2: Good **AND** Normal **AND** Normal **AND** Good **AND** Normal

$$= \frac{0.4}{1} + \frac{0.6}{2} + \frac{0.8}{3} + \frac{0.8}{4} + \frac{0.6}{5} + \frac{0.4}{6}$$

Student-3: Best **AND** Normal **AND** Very Good **AND** Good **AND** Fair

$$= \frac{0.2}{1} + \frac{0.4}{2} + \frac{0.6}{3} + \frac{0.4}{4} + \frac{0.2}{5} + \frac{0.0}{6}$$

Student-4: Good **AND** Very Good **AND** Good **AND** Bad **AND** Normal

$$= \frac{0.0}{1} + \frac{0.2}{2} + \frac{0.4}{3} + \frac{0.6}{4} + \frac{0.4}{5} + \frac{0.2}{6}$$

On comparing these with ideal performance for these parameters by using hamming distances we get,

For **Performance** we have (refer appendix for calculations),

Student-1: **0.2 units**
Student-2: **0.4 units**
Student-3: **1.2 units**
Student-4: **0.8 units**

For **Idea** we have (refer appendix for calculations),

Student-1: **0.2 units**
Student-2: **2.2 units**
Student-3: **1.2 units**
Student-4: **2.4 units**

Parameter	Student-1	Student-2	Student-3	Student-4
Report	1.6	0.2	0.2	2.4
Presentation	0.4	1.6	2.8	1.8
Original	2.2	1.2	0.2	1.8
Performance	0.2	0.4	1.2	0.8
Proof	1.8	3.2	0.8	0.4
Code	2.8	2.8	2.4	3.2
Idea	0.2	2.2	1.2	2.4
Research	1.2	1.8	0.8	2.2
Frontend	1.2	2.8	0.2	3.2
Backend	1.6	1.2	1.2	0.2
Total	**13.2**	**17.4**	**11**	**18.4**

Similarly, we can get the distances of other parameters also, let us assume some values for each of the parameters, and find the total marks obtained by the students. Now from the grades function we can assign grades to each of the student,

Student-1: **B+ Grade**
Student-2: **B Grade**
Student-3: **A Grade**
Student-4: **B Grade**

V. ADVANTAGES OF FUZZY LOGIC BASED GRADE CARD

1. Fuzzy based grade cards can be used for evaluation in many situations. It can take inputs that are not clear, not precise, and have noise in them.
2. The construction of a fuzzy based grading system is very simple. Any person with basic information about fuzzy approaches can deal with and understand the grading system.
3. It involves mathematical concepts of set theory and probability. Hence, it becomes important to try these fuzzy based evaluations and marking schemes for mathematicians.
4. Fuzzy logic comes with a lot of flexibility in decision making and reasoning. Hence, the fuzzy evaluations can even work in complex situations of partial marking, step marking, etc.
5. The fuzzy based evaluations can be merged with artificial intelligence and can be digitized easily. It saves a lot of papers and in terms of memory also, the algorithms have very low space and time complexities.

VI. DISADVANTAGES OF FUZZY LOGIC BASED GRADE CARD

1. The fuzzy logic itself is not properly defined. Researchers and scientists define the concepts according to their own ease and use them. There is no proper and standard way of dealing with problems. Hence, a grade card based on these logics will be very ambiguous. Moreover, if some scientists are asked to make this grade card, everyone would come up with his or her own approach.
2. If a student is not satisfied with his or her performance, then justifying the fuzzy based grade card is very difficult. As most of the time there is no mathematical proof for such approaches.
3. It is very difficult to standardize such a grading system throughout the country.

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4. Implementing such a grading system at the primary level of schooling is not easy. As most of the teachers would not be aware of fuzzy sets and fuzzy logic.
5. In complex evaluations, fuzzification and defuzzification are not easy. For evaluation of some important exams like final exams, a slight error in any one of them can propagate till last and can affect the student's grades.

VII. FUTURE SCOPE OF FUZZY LOGIC BASED GRADE CARD

Grading students just on the basis of the sum of their examination scores, will not give the big picture about the student, about what they know. It's just their added scores obtained from solving a few questions on paper. This is what has been reported by the National Council of Teachers of Mathematics. Now this is a challenge for the teachers, the challenge to figure out different ways of evaluating a student which would aptly describe the student's knowledge level. The proposed algorithm then comes into the picture. For the ease of access and use, a computer application can be developed to account for all the mathematical computations and algebraic calculations, which means giving input in the form of linguistic remarks and giving out quantitative results, giving out numerical values equivalent to the linguistic remarks which can be included in the marks/score obtained by the student in written examinations by converting them to letter grades or percentages. This algorithm gives a broad understanding of the working principles and how it can be applied, but it can be used to refine the results by using multiple parameters to give in depth insights of the student's performance i.e., taking the evaluation to micro-level.

For this grading system, it is required to give inputs in linguistic form only and assign some weight to each remark which would help the algorithm understand the priority and weightage of each remark.

This being done, it can be disclosed to the student and hence the student can focus on skills to enhance which would not only be beneficial for the student but also to the workplace he/she will be working in.

One can use this project for prediction of any medical disease such as Diabetes by changing the parameters to the symptoms and inputs accordingly. The output will give the degree of possibility of the disease. But this model alone will not suffice the job, a machine learning implemented model would be needed to give the accurate results based on the given past data for training purposes. Similarly, the model can be useful in factories and mills to determine the quality of the material and products by adjusting the parameters.

VIII. CONCLUSION

This report presents a model of a grade card that works on fuzzy concepts which would convert evaluators' linguistic remarks to measurable and quantitative remarks that can be used in final grading. The idea behind developing this was the scenario where students present their work in the form of presentations for demonstration of their project. Now these evaluative components, being apart from the traditional written examinations, are evaluated on the basis of linguistic remarks received by the student(s).

For example, after a group presentation, the panel of evaluators may label the performance as good/satisfactory/needs improvement or its equivalent. Now every evaluator in the panel might have a different opinion and different remarks and this might lead to a debate while coming on a common ground and deciding the final grade to be awarded because those remarks have no quantitative value and hence can be incomparable sometimes, that's where the Fuzzy Grade Card comes into the picture. The evaluators can collectively decide a set of parameters of evaluation such as code of conduct/documentation/originality etc. and a set of linguistic remarks to be given and feed them to the model before beginning the evaluation and assign appropriate weights to each of them. Now they just have to select the remarks from the set and the final measurable result will be produced after all the parameters have been assigned values. This not only eases the evaluation process for instructors but also ensures that the student's work has been evaluated from every aspect and has undergone fair evaluation.

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AUTHOR PROFILE

Parikshit Sharma, an aspiring mathematician, is dedicatedly pursuing his master's degree in Mathematics at the Birla Institute of Technology and Science, Pilani. With an insatiable curiosity for knowledge, Parikshit's research interests span across various fascinating areas. He immerses himself in the intricate world of Fuzzy Logic, unraveling the complexities of reasoning under uncertainty. Additionally, Parikshit delves into the realm of Partial Differential Equations, exploring their applications in various scientific and mathematical domains. Furthermore, his passion extends to the realms of Machine Learning and Computer Vision, where he strives to unravel patterns and create innovative solutions. Parikshit's journey is characterized by his fervor for learning and his determination to make significant contributions in his chosen fields of expertise.

APENDIX

$$Hamming\ Distance: HD(A,B) = \sum_{i=1}^{n} |\mu_A(x_i) - \mu_B(x_i)|$$

A. $Hamming\ Distance\ between\ Excellent\ and\ Excellent$:
$|1.0-1.0|+|0.8-0.8|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=0.0$

$Hamming\ Distance\ between\ Excellent\ and\ Very\ Good$:
$|1.0-0.8|+|0.8-1.0|+|0.6-0.8|+|0.4-0.6|+|0.2-0.4|+|0.0-0.2|=1.2$

$Hamming\ Distance\ between\ Excellent\ and\ Good$:
$|1.0-0.6|+|0.8-0.8|+|0.6-1.0|+|0.4-0.8|+|0.2-0.6|+|0.0-0.4|=2.0$

$Hamming\ Distance\ between\ Excellent\ and\ Fair$:
$|1.0-0.4|+|0.8-0.6|+|0.6-0.8|+|0.4-1.0|+|0.2-0.8|+|0.0-0.6|=2.8$

$Hamming\ Distance\ between\ Excellent\ and\ Bad$:
$|1.0-0.2|+|0.8-0.4|+|0.6-0.6|+|0.4-0.8|+|0.2-1.0|+|0.0-0.8|=3.2$

$Hamming\ Distance\ between\ Excellent\ and\ Very\ Bad$:
$|1.0-0.0|+|0.8-0.2|+|0.6-0.4|+|0.4-0.6|+|0.2-0.8|+|0.0-1.0|=3.6$

B. $Hamming\ Distance\ for\ Performance\ wrt\ Excellent$:
$Student-1 \coloneqq |1.0-0.8|+|0.8-0.8|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=0.2$
$Student-2 \coloneqq |1.0-0.6|+|0.8-0.8|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=0.4$
$Student-3 \coloneqq |1.0-0.2|+|0.8-0.4|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=1.2$
$Student-4 := |1.0-0.4|+|0.8-0.6|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=0.8$

$Hamming\ Distance\ for\ Idea\ wrt\ Excellent$:
$Student-1 := |1.0-0.8|+|0.8-0.8|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=0.2$
$Student-2 := |1.0-0.4|+|0.8-0.6|+|0.6-0.8|+|0.4-0.8|+|0.2-0.6|+|0.0-0.4|=2.2$
$Student-3 := |1.0-0.2|+|0.8-0.4|+|0.6-0.6|+|0.4-0.4|+|0.2-0.2|+|0.0-0.0|=1.2$
$Student-4 := |1.0-0.0|+|0.8-0.2|+|0.6-0.4|+|0.4-0.6|+|0.2-0.4|+|0.0-0.2|=2.4$

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