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A Non-Classical Approach in Analyzing Student's Performance in Academics Using Fuzzy Logic

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Abstract--- Education represents one of the person's core needs. The main objectives of learning are to educate individuals, assist them with realizing their full potential, and provide them with the skills necessary to live fulfilling lives and to fulfil their obligations. The process of administering tests and grading students is essential to learning. The entire process employs conventional evaluation approaches, in which a person's performance is purely based on the results of an evaluation and is not seen as a mark of achievement or failure. We have proposed a non-traditional activity-based approach that is based on Fuzzy Logic (FL) techniques for the evaluation of academic achievement among students. The suggested model was constructed using FL, and the results showed that this method is the most effective for assessing a learner's competence.
Keywords: Education, Fuzzy Logic, Fuzzy Set, Linguistic Variable, Membership Functions

1. Introduction

It is the fundamental right for every citizen to have an access to quality education. This aids in separating right from wrong. Our intellectual standards are raised, and our sensibility is refined. In this way, prejudice can be efficiently dispelled by enlightenment. It strengthens your capacity for reasoning and equips you to reach simple conclusions. It is also essential for all sorts of progress. Learning has the potential to ignite a change for the better. One of the most essential components of our educational system is the evaluation of a student after he completes an assignment or a certain project. Evaluating students has historically been the most time-consuming, divisive, and difficult component of the educational system. The process of instruction and learning as well as the methods used to evaluate students' progress during instruction have unique gaps in the educational system [2]. The current grading system is inadequate and imprecise to identify successful or unsuccessful students. It is appropriate to link teacher evaluations to students' test results in order to keep educators accountable for how much their students are learning. The activities of measuring and evaluating are energizing and essential to the learning process. The assessments each student receives are greatly influenced by the many teachers that are assigned to them; if assessments are handled poorly, it will restrict the students' opportunities in the present and the future.

It is necessary to rate students in a way that is more objective and transparent. Amendments to the system of education are needed, not just in terms of the curriculum but also in terms of how students are assessed. The achievements of the students are often statistically expressed based on the results of the exams. A fair and consistent evaluation system that is regularly reviewed and improved should be beneficial to all students. The problem becomes significant if the evaluation is incorrectly conducted [1].

The main problem with the traditional grading method is the absence of information about the standards for the "final result" and the assessment procedures that were used. Other problems with the traditional method for assessing include the inability to specify the standards on which students should be graded, the existence of multiple reviewers with differing opinions on the responses provided by students, the lack of accountability in the system, the potential for some students to receive higher marks for the same response than others based on their moods, and the potential for personal factors like fatigue, stress, and peer pressure.

The assessment of a student's academic performance generally involves a number of variables, each of which calls for a number of conclusions that are frequently based on thin evidence. Making decisions will be more challenging in this circumstance because we are working with ambiguous facts. These techniques used in conjunction with standard approaches have limitations when dealing with data that is this unclear and inconsistent.

The use of fuzzy logic in academic settings to assess student performance is a relatively new innovation. Before developing performance measurements, a useful tactic could be to divide students into various groups based on cognitive and affective factors.

It is hoped that fuzzy model-based reasoning will provide an alternative approach for handling various sorts of flawed data, which typically mirrors how people perceive and develop views. Fuzzy logic naturally handles ambiguity and imperfection by providing a human-centered conceptual description. In this investigation, fuzzy logic techniques were used to assess pupils' academic performance.

2. Fuzzy Logic

The fuzzy logic theory was initially introduced by Prof. Zadeh [6]. The fuzzy logic controller is regarded as a successful strategy because it yields results that are superior than those given by traditional control algorithms. Fuzzy logic can be used in place of linguistic and subjective features of the real world in computing. To address problems where there are no clearly defined criteria, fuzzy logic is applied. Since fuzziness and ambiguity are common in many decision-making challenges, good decision-making models should be able to handle them. Figure 1 shows the essential structure of a fuzzy logic controller.

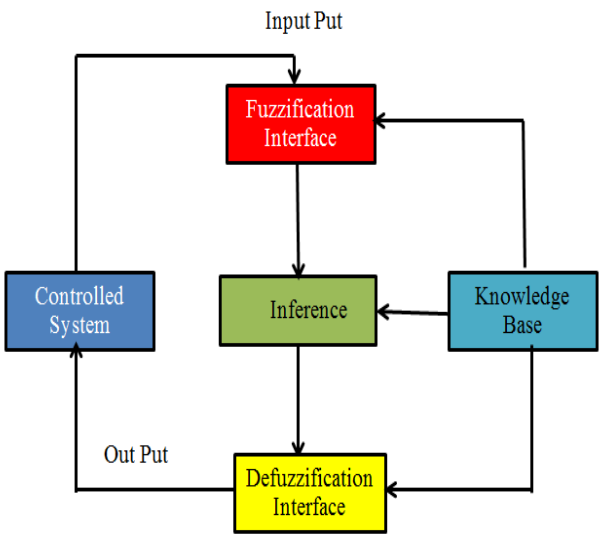

Fig. 1

A fuzzy controller accepts input values, performs certain calculations, and outputs a value, just like a typical system does. The four main components of the fuzzy system are shown in Fig. 1. It transforms inputs with real or precise values into ones with fuzziness. An inference engine uses a fuzzy reasoning technique to provide a fuzzy outcome. The outcome of the latter procedure is transformed into precise values by a defuzzifier. Membership functions and fuzzy rules are components of a knowledge base, sometimes known as a rule base [7].

Fuzzy Set

The following set pairings are considered to be a fuzzy set ‘A’ in a universe of discourse ‘X’.

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

where, $A=\{ \mu_A (x): x \in X\}$ is a mapping called the membership function of fuzzy set A and $\mu_A (x)$ is the membership value of $x \in X$ in the fuzzy set A.

We write (1) in the following form:

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

However, we often equate fuzzy sets with their membership functions.

Linguistic Variable

Although mathematical variables normally have numerical values, non-numeric values are frequently used in FL applications to facilitate the explanation of rules and facts. A fuzzy set can be used to describe the value of the variable. A linguistic variable is a fuzzy variable. Fuzzy logic's central concept of linguistic variety is essential to its applications. The values of a linguistic variable are words from a natural language.

The linguistic variable "tall" in the aforementioned example can be used to determine how tall a person might be. This variable has several possible values, including "very short," "short," "average," "tall," and "very tall." A linguistic variable, which is a higher-order variable than a fuzzy variable, accepts fuzzy variables as values. A linguistic variable is characterized by: (X, T(X), U, M), where X---name of variable, T(X) ---the term set of X, the set of names or linguistic values assigned to X, U---Universe of Discourse, M---semantic rule associate with each variable.
For example, If X is "Height" which is defined as linguistic variable then, T (Height) = {Very Short, Short, Average, Tall, Very Tall}
U= {3, 8}
M= defines the membership function of each fuzzy variable for example, M (Very_tall) = the fuzzy set for height above 7^{ft} with membership of μ_{very_tall}.

Membership Functions

Fuzzy logic is a word used to describe fuzziness; it is not fuzzy logic per se. Its membership functions serve as the best example of this fuzziness. In fuzzy logic, the degree of truth is expressed by the membership function. It describes how each input point is transformed into a membership value between 0 and 1. These membership functions are used to change the non-fuzzy input values to fuzzy linguistic values throughout the fuzzification and defuzzification processes.

Formal Definition of membership function:

Let us consider fuzzy set A, A = {x, $\mu_A(x)$ | x Є X} where $\mu_A(x)$ is called the membership function for the fuzzy set A. X is referred to as the universe of discourse. The membership function associates each element x Є X with a value in the interval [0, 1]. In fuzzy sets, each element is mapped to [0, 1] by membership function.

Here, "membership function" is represented by μ_A (x). The value of this function lies between 0 and 1. This value denotes the "degree of membership" of element x in set A. Members of a fuzzy set, also known as a membership grade or degree of membership, are members to some extent. The membership grade is a representation of the degree of membership in the fuzzy set. The degree of membership increases as the number in [0, 1] increases. Fuzzification is the transformation of x to $\mu_A(x)$. According to the fuzzy theory, the membership function of set A, function $\mu_A(x)$, defines the fuzzy set A of the universe X.
We already discussed this point.
$\mu_A(x): X \rightarrow [0,1]$, where
$\mu_A(x) = 1$ if x is totally in A;
$\mu_A(x) = 0$ if x is not in A;
$0<\mu_A(x)<1$ if x is partly in A.
This set allows a continuum of possible choices. For any element x of universe X, membership function $\mu_A(x)$ equals the degree to which x is an element of set A. This degree, a value between 0 and 1, represents the degree of membership, also called membership value, of element x in set A.

Basic Fuzzy Set Operations

A fuzzy set 'A' in a universe of discourse 'U' is characterized by a membership function µA which takes the values in the unit interval [0, 1] i.e.

$$\mu_A: U \rightarrow [0, 1]$$

The value of μ_A represents the grade of membership of µ in A and is a point in [0, 1].

Fuzzy Set Operators

1) Union

The maximum of the two individual membership functions is the definition of the membership function of the union of two fuzzy sets A and B with the membership functions µA and µB, respectively. They call it the maximal criteria. In boolean algebra, this union operation is equivalent to the OR operator.

$$\mu_{AUB} = \max(\mu A, \mu B).$$

2) Intersection

The minimum of the two separate membership functions is referred to as the membership function of the intersection of two fuzzy sets A and B with respective membership functions μA and μB. It is referred to as a minimum standard. The 'AND' operator in boolean algebra is equivalent to this intersection operation.

$\mu_{AUB} = \min(\mu A, \mu B)$.

3) Complement

The negation of the stated membership function is known as the membership function of the complement of a fuzzy set A with the membership function μA. It's referred to as a negative criterion. In boolean algebra, it is analogous to the NOT operator.

$\mu_{\bar{A}} = 1 - \mu_A$

Let us discuss these fuzzy set operators by taking an example. Here we have two fuzzy sets with some predetermined values.

A1= {1\1.0 + 0.75\1.5 + 0.45\2.0 + 0.35\2.5 + 0.15\3.0}

A2 = {0.95\1.0 + 0.6\1.5 + 1\2.0 + 0.15\2.5 +0.0\3.0}

First let us consider fuzzy union operation which has been discussed earlier the formula for computing union of two sets is

A1 ∪ A2 = max (μ_{A1} (x), μ_{A2} (x)).

Here we have to compare two elements i.e. one element from each set but the denominator value should be identical. For example the first element of set A1 is {1\1.0} and first element of set A2 is {0.95\1.0}. Here the value of denominator is same, hence the numerator value can be compared and in union we have to take the max of two. In this case it will be,

A1 ∪ A2 = {1\1.0}

Likewise the complete union of these two sets is,

A1∪A2={1\1.0+0.75\1.5+1\2.0+0.35\2.5+0.15\3}.

Similarly, the intersection operation works by taking the minimum of two values from the two sets. The final result after employing intersection for the above two sets A1 and A2 we have,

A1∩A2={1\1.0+0.75\1.5+1\2.0+0.35\2.5+0.15\3}.

3. Proposed Model And Implementation

The creation, transformation, and computation of qualitative weights and scores are all covered in this section. A questionnaire that was developed in accordance with the limitations and guidelines offered by several experts on the evaluation committee has been taken into consideration. Every question used in this manner is denoted by "Criteria" and "Sub-criteria" in Table 1. The reviewers then provide the scores using this form. Each of the evaluation criteria was given a score between 0 and 100, which should equal 100 overall, for each survey respondent. Similar to this, they gave each sub-criteria a score between 0 and 100, resulting in a sum of 100 for each sub-criteria group that was related to that particular criterion. After compiling the results from each of the forty survey respondents, the mean scores (significance levels) for each of the criteria and the associated sub-criteria are determined. Table 1 lists the criteria, together with the sub-criteria items that relate to them, and the accompanying mean scores.

The qualitative weights and their accompanying requirements for students are defined in Table 1 of the score table. The sub-criteria mean scores in Table 1 might be used to create the weight matrices A1, A2, A3, A4, and A5 for each of the sub-criteria. These weight matrices are denoted in A1=(0.25,0.25,0.25,0.25)

A2=(0.26,0.20,0.26,0.28)

A3=(0.23,0.27,0.28,0.22)

A4=(0.25,0.25,0.25,0.25)

A5=(0.23,0.27,0.28,0.22)

Similarly, the generalized weight matrix A is obtained from the criteria mean scores as follows: A=(0.38,0.18,0.17,0.11,0.16).

In order to obtain the results for the implementation phase, it was assumed that there is a party committee with five members. It was supposed that the members would give scores to candidates' features among a scale of 1 to 5 (Very High=5, High=4, Medium=3, Low=2, Very Low=1). By this way, the matrices are derived from these

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party members' assessment and the results are evaluated by calculating the union of these matrices. It should be noted that the member set size used in this implementation is not a mandatory value or limit. This is a discretionary value chosen for this study and it can be changed to different alternative values in similar studies in the future.

Table1: Mean Scores

CRITERIA	MEAN SCORE	SUB-CRITERIA	MEAN SCORE FOR SUB CRITERIA
Academics	38	Subject1	25
		Subject2	25
		Subject3	25
		Subject4	25
		Total	***100***
General Studies	18	Leadership skills	26
		Motivational Capability	20
		Team Work	26
		Problem Solving	28
		Total	***100***
Communication Skills	17	Verbal Ability	23
		Language Fluency	27
		Interaction Ability	28
		Non-Verbal Ability	22
		Total	***100***
Attendance	11	Subject1	25
		Subject2	25
		Subject3	25
		Subject4	25
		Total	***100***
Other Skills	16	Listening Skills	23
		Creativity	27
		Technological Awareness	28
		Social Responsibility	22
		Total	***100***

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Table 2: Scores given by Evaluators.

CRITERIA	SUB-CRITERIA	Scores Given By Five Evaluators				
Academics	Subject1	4	4	4	4	4
	Subject2	3	2	1	2	3
	Subject3	4	1	2	2	1
	Subject4	5	2	2	3	3
General Studies	Leadership skills	5	4	4	5	5
	Motivational Capability	5	5	4	4	3
	Team Work	5	5	3	3	1
	Problem Solving	1	1	2	2	5
Communication Skills	Verbal Ability	5	5	4	4	3
	Language Fluency	5	4	5	4	3
	Interaction Ability	5	4	4	4	3
	Non-Verbal Ability	5	5	4	4	3
Attendance	Subject1	5	5	5	5	5
	Subject2	5	5	4	4	1
	Subject3	5	4	3	2	1
	Subject4	5	3	3	2	2
Other Skills	Listening Skills	4	4	3	3	3
	Creativity	4	4	4	4	4
	Technological Awareness	5	5	5	4	4
	Social Responsibility	3	3	2	2	5

With respect to these scores, the final cumulative score for that candidate has to be found out by implementing fuzzy logic methodology. To establish this, first, the scores for each of the criteria and its relevant sub-criteria should be transformed into an appropriate format so as to be used in the fuzzy process. For instance, as it could be seen in Table 2; “Technological awareness” sub-criteria in “other skills” of the candidate gets 5 points from three members and 4 points from the other two members. The other sub-criteria are also analyzed in the same way. Using these points, a matrix composed from fuzzy numbers can be obtained, which is denoted in Table 3.

Table 3: Fuzzification of other skills

	Very High	High	Average	Low	Very Low
Listening Skill	0.0	0.4	0.6	0.0	0.0
Creativity	0.0	1.0	0.0	0.0	0.0
Technological Awareness	0.2	0.0	0.4	0.4	0.0
Social Responsibility	0.6	0.4	0.0	0.0	0.0

Table 4: Matrix for Human Skills

Thus, the matrix for "Human Skills and Qualifications" could be written as:

0.0	0.4	0.6	0.0	0.0
0.0	1.0	0.0	0.0	0.0
0.2	0.0	0.4	0.4	0.0
0.6	0.4	0.0	0.0	0.0

The other four matrices are created using the same process. Each of these matrices must then be processed using the weight matrices and the union operation. Remember that C1 = A1 * B1 is how the union operation is defined. Thus, the appropriate quantitative evaluations may be established using this definition.
For instance we will consider "other skills" criteria:

C1= (0.23,0.27,0.28,0.22)*{{0.0,0.4,0.6,0.0,0.0}, {0.0,1.0,0.0,0.0,0.0},{0.2,0.0,0.4,0.4,0.0},{0.6,0.4,0.0,0.0,0.0}}.
By applying min and max criterion we will get the result as: C1=(0.22,0.27,0.28,0.28,0.0).
Hence, the matrix obtained from other criteria can be denoted as follows: C2=(0.25,0.25,0.25,0.25,0.25), C3=(0.26,0.26,0.28,0.28,0.28),C4=(0.25,0.25,0.25,,0.25,0.2), C5=(0.22,0.27,0.28,0.28,0.28).
Final fuzzy score= A*C, (0.38,0.18,0.17,0.11,0.16) *
{{0.22,0.27,0.28,0.28,0.0}{0.25,0.25,0.25,0.25,0.25}
{0.26,0.26,0.28,0.28,0.28}{0.25,0.25,0.25,,0.25,0.2}
{0.22,0.27,0.28,0.28,0.28}}= (0.28,0.28,0.25,0.22,0.2).

In the final step, this final fuzzy score matrix will be operated through defuzzification process. Thus, a final score will be determined for the candidate. It should be noted that, after defuzzification, the final score for any candidate can be any quantitative value ranging between 0 and 100.
Y=((0.28)*20+(0.28)*40+(0.25)*60+
0.22)*80+(0.20)*1.0)/(0.28+0.28+0.25+0.22+0.20) = 77.6
After these calculations, final score is found out to be 77.6, retrieving the scores by filling in the entries denoted in Table 2 and executing the same subsequent steps, the final score for each candidate was obtained.

4. Conclusion

It is necessary to evaluate student performance and learning attainment better, which necessitates promoting educational innovations. This study provides a novel fuzzy logic-based approach to assessing students' academic performance. When assessing a student's attributes, both intellectual and psychological traits are taken into consideration. The results suggest that the model in this study may offer a promising alternative to the traditional evaluation approach by significantly lowering subjectivity, ambiguity, and qualitative errors. It is shown that it is simple to evaluate pupils using FL methods. The suggested approach is more favorable, open, and fair to all pupils.

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