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Analysis of Students' Performance by Fuzzy Inference Technique

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Abstract:

The performance of a student in a subject includes two main factors: one is performance in a single chapter and other is performance in the remaining chapters. In this article, performance of the class x standard students in mathematics subject in special reference to the chapters of the subject is discussed. As per as the syllabus of NCERT class x mathematics subject, seven branches namely algebra, geometry, trigonometry, mensuration, co-ordinate geometry, probability and statistics are considered in most of the institutions. The potentiality to monitor to develop and progress of students' performance in a particular subject is a critical issue to the overall academic performance of a student. This study tries to approach this issue by considering the advantage of fuzzy inference technique in order to classify the data obtained from students' scores. It is very necessary to analyse the above-mentioned two factors for the good performance of each subject and to get good result of the student in any institute. To analyse the performance of individual student, in this paper a methodology to improve the above-mentioned two factors is adopted. The whole data obtained from student's response test is divided into various ranges through fuzzy logic system. In this papers, fuzzy logic system, rules and membership functions, linguistic variables and the application of performance analysis methodology with the help of fuzzy logic system are included. Two membership functions namely, trapezoidal and triangular membership functions are considered. Fuzzification of input data (students' scores) by creating a fuzzy inference system (FIS) chapter wise, next each FIS output is passed to another FIS with one output of the final FIS. The performance value is calculated based on the scores of the 'remaining chapters' with or without the scores of 'one chapter' of the same subject.

Introduction: In every academic institution the achievement or the success of a student is determined or measured by the academic performance, or how well a student meets the standards set out by the Academic board or the Policies of the Government of Education or the Institutional rule and regulations. In general, the assessment of a student in every institution is used to determine the skills, attitudes and faith in their subjects. It is also used to predict the progression or degradation of the student in due time and the institute can inform the students those who are needed to concentrate or to improve and, some remedial classes, tutorial classes, coaching, workshop or training programmes are organised.

Objectives: The proposed objective of this study is to determine the students' academic performance using fuzzy logic model instead of using traditional method of evaluation of assessment. Using linguistic variables instead of numerical values, fuzzy inference system (FIS) is implemented.

Methods: Here, fuzzy methodology is considered. In the methodology, the crisp value will describe the students' score in mathematics subject questionnaire. In the step of fuzzification, the crisp value i.e., the students' score is converted into fuzzy input value with the help of a suitable membership function which consist of combination of triangular and trapezoidal membership functions in this study. Different types of fuzzy

rules are defined in the form of if-then rule for the evaluation of student academic performance. In this method, the final output or the performance value is computed with the help of a suitable defuzzification method. In this study, the centre of area (COA) method for defuzzification is used to obtain the performance evaluation

Results: In this paper, a new method of classifying the students' performance in a particular subject is described based on *Fuzzy Logic Technique*. Different types of class distribution were observed for the evaluation of performance including and excluding the performance of one chapter. In this study, *Fuzzy Logic* is used as a technique of *soft computing* to evaluate the students' performance in a particular subject. Here a set of questionnaires was prepared with the discussion from subject experts. A total of 50 items are included in the questionnaire and 40 students are tested from the government high schools of Baksa District, India

Conclusions: Through this paper it can be concluded that this system is very much useful in order to analyse the performance of a student in a particular subject. This methodology can also be applied to those students that are under the performance category of 'poor' or 'very poor'. In this study the experiments are carried out using *Matlab fuzzy toolbox* on *Windows 10 platform*. The proposed fuzzy model was tested with the performance data from the class x mathematics text book comprising all the chapters. Here a set of questionnaires was prepared with the discussion from subject experts.

Keywords: Linguistic variables, membership functions, performance score, performance analysis

1. Introduction

In every academic institution the achievement or the success of a student is determined or measured by the academic performance, or how well a student meets the standards set out by the Academic board or the Policies of the Government of Education or the Institutional rule and regulations. In general, the assessment of a student in every institution is used to determine the skills, attitudes and faith in their subjects. It is also used to predict the progression or degradation of the student in due time and the institute can inform the students those who are needed to concentrate or to improve and, some remedial classes, tutorial classes, coaching, workshop or training programmes are organised.

In order to guide and motivate students towards active engagement in their own learning and understanding, the mechanism of assessment has a great role. For this, providing instructors to improve teaching methods in every educational institutional is needed. The assessment provides, the feedback from both the instructors or teachers as well as the students. It also facilitates the students in diagnosing their own learning which can help students becoming more effective, self-study, self-oriented, self-assessing, self-efficiency. Student's performance in a particular subject is directly proportional to their academic result. The purpose of assessment in educational institution includes certification, placement, promotion, diagnosis, evaluation, aiding learning and improving teaching. The result of assessment may be a simple statement such as percentage, marks, grade, class or a certificate. In recent studies, in order to know what a student learned or what they can do in greater detail, different types of documentations are used, such as performance analysis or evaluation by fuzzy inference technique. If a student is weak in a particular subject, then we cannot hope excellent result from that student. There are two main factors, on which the performance of a student in a subject mostly depends: first one is

'performance of the particular branch' and the other is 'performance of the remaining branches. In order to get excellent performance in a subject, it is necessary to be very good performance in all the branches of that subject.

2. Consequence of Performance Evaluation

a. Institute Administration

Every educational institution plays an important role to raise development of critical thinking, problem-solving skills, intellectual growth, knowledge acquisition, respect, responsibility and empathy. It also plays various crucial role among the students as well as in the society such as economic development, personal development, skill development, research and innovation, cultural preservation, socialization, transmission of knowledge. Educational institution helps and can provide an individual to become engaged and informed citizen by teaching them about culture, social issues, government. It also enables the expansion of human knowledge and to facilitate its access to all those who want to use it. In every educational institution, the performance evaluation of students can help the institute to know about the performances of the student time to time. A structured learning environment with qualified teachers or instructors who can facilitate the acquisition of knowledge and skills can be provided from an educational institution. Institute administration in every academic institution has an active part for overall development of the institute. The main pillar of an institute is formed by the institute administration and students, while the teachers stand in between them. Academic curriculum, rules and regulations of an institute is administered by the institute administration. The administration can identify the progress of the students through performance evaluation conducted by the teachers. In case of some unfavourable situation, the administration can administer the institutional decisions and can also adopt some policies to recruit teachers to upgrade and to enhance the performance of the students so that the institute can achieved overall good academic performance.

b. Teachers

Through performance evaluation, every teacher can review the ability of all informative and instrumental principles. Teachers can identify or investigate the inability of the student using assessment or evaluation. They can also inspire and serve as a role model and play an important role in the holistic development of the students. If the students find the questionnaires, assignments difficult, it can be suggested the teachers to change the methods and techniques and can revise to help the students to gain the relevant knowledge. In case of class test or any kind of examination, the students must be notified about the chapters or syllabus by the teachers, otherwise it could result poor performance by the students. Students who got motivated or inspired can achieved higher scores or performance in comparison to those who left out unmotivated. Therefore, the teacher plays an important role in the performance evaluation of the students.

c. Students

The performance evaluation can engage the interest of students. The performance evaluation determines what students know and whether they can utilise or use their knowledge or not. There is a strong relationship between students' perceptions about assessment and their approaches to learning.

From students' point of view, assessment has a positive effect on their learning and is 'fair' the assessment relates to authentic tasks, represents reasonable demands, encourages students to apply knowledge to realistic contexts, emphasizes the need to develop a range of skills, and perceived to have long-term benefits (Sambell, McDowell & Brown). Since conventional assessments are traditional methods of evaluating a students' knowledge mainly through multiple choice and essay typed format, the students perceive the multiple-choice format more favourable than essay or descriptive type times. Those students with poor knowledge and learning skills does not favour essay or descriptive type assessment, on the other hand students with both good knowledge and learning skills favour essay or descriptive type assessment or examination. In order to achieve deep learning and conceptual understanding, the assessment methods and teaching practices encourage the students.

3. Some Ways of Performance Evaluation

Different types of patterns for scaling are chosen by the educational institution as a performance-index. The percentage and CGPA (Cumulative Grade Point Average) system are the main two patterns are used in most of the institution. In percentage pattern, an average percentage of score of marks are computed and listed as a performance index. In case of scaling pattern, most of the institution followed as shown in Table-1:

Table-1: Scaling Pattern of Percentage

Percentage (P)	Performance Index (PI)
$P \geq 80\%$	Distinction/ Excellent
$80\% > P \geq 60\%$	First Division
$60\% > P \geq 45\%$	Second Division
$45\% > P \geq 30\%$	Third Division
$P < 30\%$	Fail

The classification of percentages and the performance index differs from one board of education to other or may vary university to university. Also, it may vary stream wise in different board of education. In case of CGPA also, the grading system differ from one board of education to other or university. Most of the universities or educational institution followed the 10-point CGPA as shown below in Table-2.

Table-2: Scaling Pattern of CGPA

CGPA		Performance Index (PI)	
Range of Relative Percentile	Grade Point	Letter Grade	Performance
90 – 100	10	A	Excellent
75 – 89	8	B	Very Good
55 – 74	6	C	Good
40 – 54	4	D	Average
30 – 39	2	E	Pass
Below 30%	0	F	Fail

Like in mathematics subject, here we consider the branches as algebra, geometry, trigonometry, mensuration, co-ordinate geometry, probability and statistics. In this study, we will consider both the factors are necessary. If any one of these factors is very good and other is very weak, then the performance of that student will not be put in the category of excellent. Depending on the above-mentioned two factors, the performance of a student is divided into very poor, poor, satisfactory and excellent. Also, from this the students those are in the category of 'very poor' and 'poor' can be identified.

The overall performance of the subject of each of the student are identified and, is compared with individual performance. As per as the student's response test, the primary data are collected to investigate the subject performance. A fuzzy rule with two input variables and one output variable is applied in this study. The performance of each of the student is divided as very poor, poor, satisfactory and excellent as a fuzzy set having degrees of membership between 0 and 1. The performance of each of the branch of the whole subject is identified for the individual student.

4. Fuzzy Logic and Modeling in Evaluation of Performance

Fuzzy Logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1, instead of just the traditional values of true or false. It is used to deal with imprecise or uncertain information and is a mathematical method for representing vagueness and uncertainty in decision-making. If the model uses formalisms of fuzzy logic, then it is called a fuzzy model. The simplest fuzzy model consists of a set of rules with an "if – then" structure: If < condition 1 > and … and < condition n > then < conclusion >. In traditional mathematical logic the classical two value logic are, ''true'' or ''false,'' usually expressed as ''1'' or ''0.'' Nevertheless, in the fuzzy logic theory, a proposition could be considered as ''partial true'' or ''partial false.'' The degree that a proposition belongs to ''true'' or ''false'' can be measured by degree of membership in fuzzy logic theory. Fuzzy logic is a control logic that uses degrees of input and output to simulate human reasoning by integrating rule-based implementation. This technique can manipulate and manages uncertain or imprecise information or the facts. Includes connectives like conjunctions and disjunctions to handle degrees of uncertainty. In addition to this, there is a set of inference rules for making decision statements. These rules help to represent a type of human expertise. Fuzzy logic extends the classical Boolean logic. For a given universal set (crisp set) X, a fuzzy subset A of X is characterized by its membership function as

$\mu_A: X \to [0,1]$,

Where for $x \in X$ the number $\mu_A(x)$ describes the degree of membership of x in the fuzzy set A or in other words, the truth value of the statement '*x is the element of A*'. In other words, we can say that the membership function represents the degree of truth in fuzzy logic. we can also say that, $\mu_A(x) = 1$, 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. Mainly, there are four parts of fuzzy logic inference in fuzzy logic system: fuzzification, inference method, fuzzy rule base and defuzzification. The membership functions can also be said as the building blocks of fuzzy set theory, that is, the fuzziness in a fuzzy set is determined by its membership function. Some basics on fuzzy membership functions are: $\alpha - cut$, strong $\alpha - cut$, support, height, normal, subnormal, convex, standard complement, standard intersection, standard union, equilibrium points. For different

problems, different kinds of membership functions were chosen according to the analysis of experts in related field. The most frequently used membership functions are triangular membership, trapezoidal membership function, and sigmoid membership function.

Most of the researchers applied the fuzzy techniques in the process of evaluation of students' performance by using linguistic terms in assessing performance of the students. Ramjeet Singh Yadav et al [1] proposed a fuzzy expert system (FES) for the evaluation of student academic performance based on fuzzy logic techniques. In this paper a suitable fuzzy inference techniques and some associated rule has been discussed. This paper also describes the principles that could be applied by educators to evaluate the students' academic performance. Chang and Sun [2] presented a method for fuzzy assessment of learning performance of junior high school students. Khairul A. Rasmani and Qiang Shen [3] presented a fuzzy rule-based approach for aggregation of performance of students in academic. In this paper, it is discussed that how the principles of Fuzzy Logic can be applied by the Educators to evaluate the students' performance in a particular subject. Ma and Zhou [4] also presented a Fuzzy set approach to the assessment of student-centered learning. N. Sarala and R. Kavitha [5] used the principles of fuzzy logic to evaluate the students' mathematics skill. Fuzzy logic system can be applied in case of uncertainty and also it can help to model some common-sense reasoning which are very difficult for general techniques.

5. Objectives

The proposed objective of this study is to determine the students' academic performance using fuzzy logic model instead of using traditional method of evaluation of assessment. Using linguistic variables instead of numerical values, fuzzy inference system (FIS) is implemented.

6. Methods

In this study, the steps of the fuzzy methodology as shown below are considered.

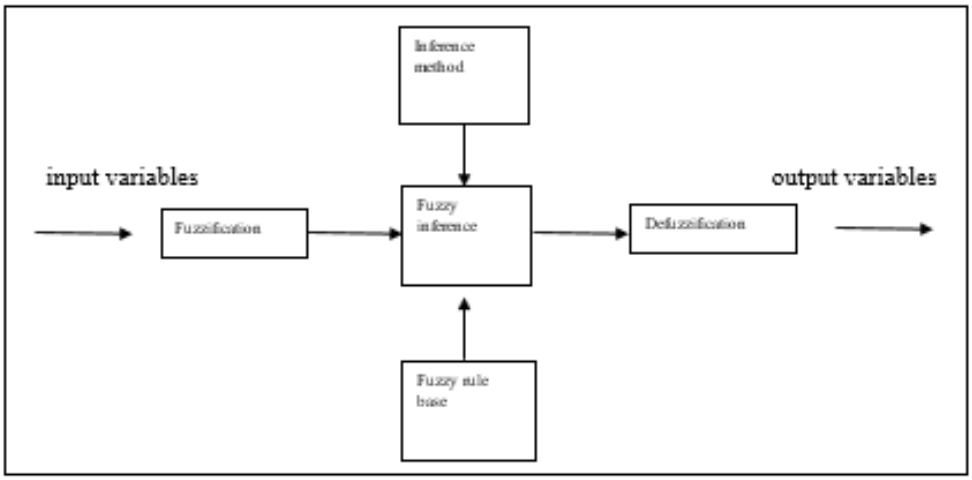

Fig.1: Steps of fuzzy methodology

In the above methodology, the crisp value will describe the students' score in mathematics subject questionnaire. In the step of fuzzification, the crisp value i.e., the students' score is converted into fuzzy input value with the help of a suitable membership function which consist of combination of triangular and trapezoidal membership functions in this study.

The evaluation of students' academic performance usually consists of several components, including their judgements which are based on imprecise data. Different types of fuzzy rules are defined in the form of if-then rule for the evaluation of student academic performance. In this method, the final output or the performance value is computed with the help of a suitable defuzzification method. In this study, the centre of area (COA) method for defuzzification is used to obtain the performance evaluation. The fuzzification process has been carried out using fuzzy tool box MATLAB. Here, the FIS is created with two input and one output. The two inputs are 'each chapter' and 'remaining chapter' and one output is the 'performance of subject'.

7. Formation of Membership Function from the data obtained

In fuzzy set theory, the most commonly used range of values of membership functions is the unit interval $[0, 1]$. The membership function of a fuzzy set A is denoted by μ_A which is defined as:

$\mu_A: X \rightarrow [0, 1]$.

The membership function represents the degree of truth as an extension of valuation.

For each chapter, each input variable has three membership functions (two trapezoidal and one triangular). The fuzzy sets of the input variables (one branch) are given in Table-3 and the membership functions for input variable (one branch) are shown in fig. 2

Table-3: fuzzy set of input variable (one chapter)

Linguistic variable	Interval
Weak (W)	(0, 0, 25, 45)
Average (A)	(30, 50,70)
Good (G)	(55, 75, 100, 100)

8. Evaluation of Performance by Fuzzy Inference Technique

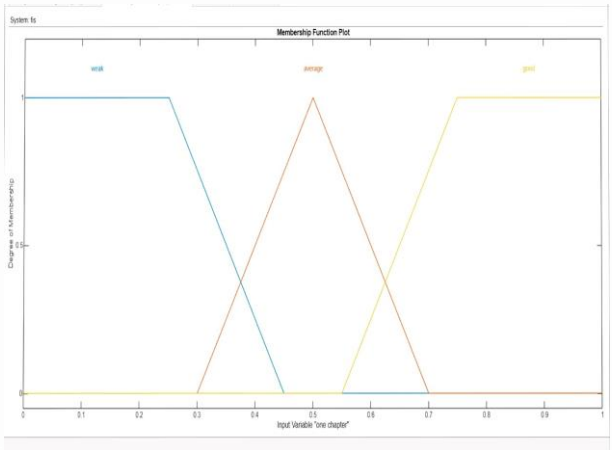

Fig. 2: Membership function for input variable (one chapter)

For remaining chapters, each input variable has three membership functions (two trapezoidal and one triangular). The fuzzy sets of the input variables (remaining chapter) are given in Table-4 and the membership functions for input variable (remaining chapter) are shown in fig. 3

Table 4: Fuzzy set of input variable (remaining chapters)

Linguistic variable	**Interval**
Weak (W)	(0, 0, 25, 45)
Average (A)	(30, 50,70)
Good (G)	(55, 75, 100, 100)

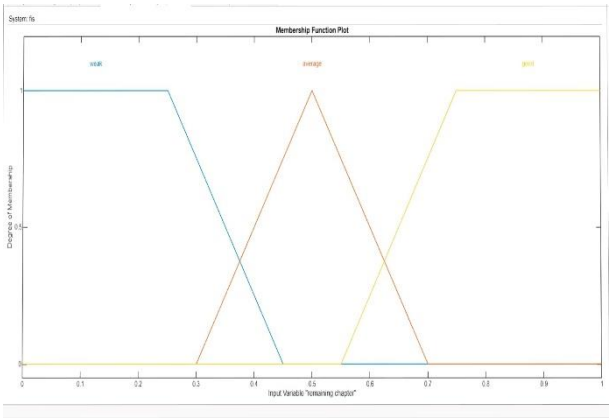

Fig. 3: Membership function for input variable (remaining chapters)

The fuzzy sets of the output variables are given in Table-5 and the membership functions for output variable are shown in fig. 4. Here, the out variable has three membership functions (one triangular and two trapezoidal).

Table-5: fuzzy set for output variable

Linguistic variable	**Interval**
Poor	(0, 0, 20, 35)
Below Satisfactory	(25, 35, 45)
Satisfactory	(40, 50, 60)
Above Satisfactory	(55, 65, 75)
Excellent	(55, 75, 100, 100)

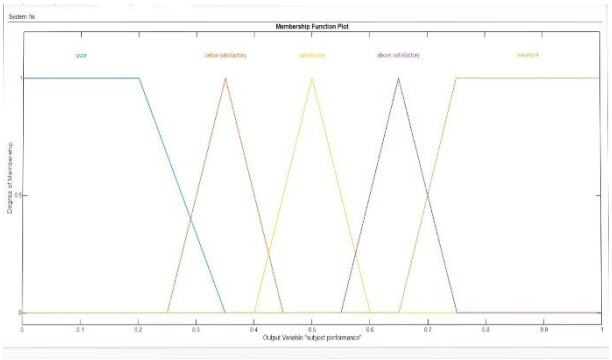

Fig. 4: Membership function for output variable (performance value)

In this experiment the linguistic variable is based on an interval that refers to the performance level given by the subject experts as shown in Table 3, 4. The output of these FIS gives the chapter wise/ branch wise performance value of each student participated in the performance test conducted through a set of questionnaires.

9. Formation of Rules and generation of inference

To analyse the accurate academic performance of a student, 'marks obtained' and 'attendance' are necessary. Similarly, to analyse the performance of a subject, the performances of each chapter and the performances of the remaining chapters are necessary. Here, we assume that the performance of a student in a subject depends upon both the factors. Therefore, in order to get excellent performance of a student, it is necessary to have the above-mentioned factors as good input variable. In our approach, we formed the following various rules with two input variables and one output variable, from the discussion with the academic experts. Here, the linguistic variable rules called as "*if-then*" is used to determine the input and output membership functions.

Table 6: Set of Fuzzy Rules by "*if-then*" rule

		Remaining chapters		
		W	A	G
One chapter	W	Poor	Below Satisfactory	Satisfactory
	A	Below Satisfactory	Satisfactory	Above Satisfactory
	G	Satisfactory	Above Satisfactory	Excellent

10. Analysis of Performance with Fuzzy Logic System

Here we are executing the performance analysis and the improvement methodology with fuzzy logic. The input variables 'one branch' and 'remaining branch' are defined with the help of four membership functions as very weak, weak, good and very good. Also, the output variable 'subject performance' is defined as very poor, poor, satisfactory and excellent. Figure-2 shows two input variables 'one branch' and 'remaining branches' and one output variable 'subject performance'. Figure-3 shows the membership functions for input variable 'one branch'. Figure-4 shows the membership functions for

input variable ‘remaining branches’, Figure-5 shows the membership functions for output variable ‘subject performance’. Figure-6 shows the formation of the rules for the above-mentioned two input variables and one output variable. Totally there are 112 combinations of various rules. Figure-5 shows the analysis of the performance. With the help of these parameters like ‘one chapter’, ‘remaining chapters’ and ‘subject performance’, a 3-D surface figure is shown in figure-6. Also, the figure.5 shows an example of the performance of a student in ‘one chapter’ 0.6 (i.e., 60 %) and ‘remaining chapters’ 0.8 (i.e., 80 %) is 75.4 %.

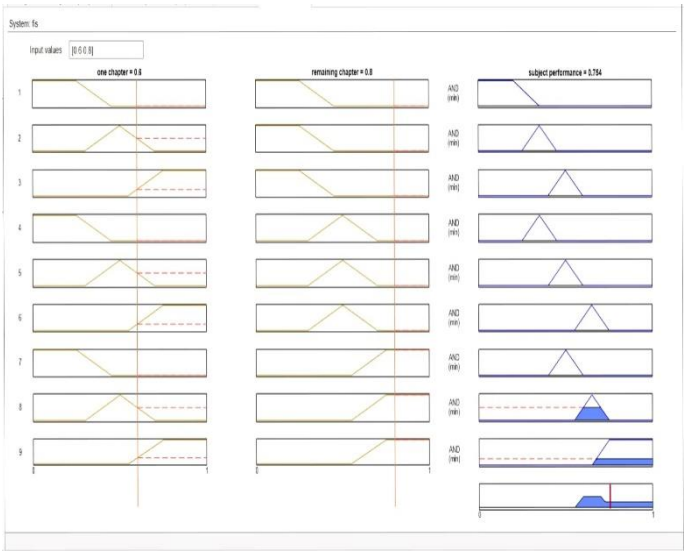

Fig. 5: Performance value for one chapter and the remaining chapters scores of 60 and 80

In Fig.6, the overall performance evaluation space is depicted. In the figure, the output value is greatly affected for the input range value between 70-85 on the marking scale.

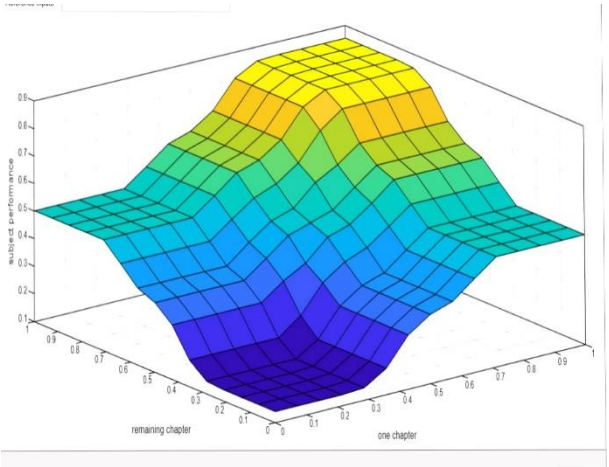

Figure 6: 3- D surface view of the performance evaluation

11. Results

In this paper, a new method of classifying the students’ performance in a particular subject is described based on *Fuzzy Logic Technique*. Different types of class distribution were observed for the evaluation of performance including and excluding the performance of one chapter. When the scores from one

chapter were excluded then either the students may tend to shift to the *upper-class* distribution or to the *lower-class* distribution. Therefore, the performance score of *one chapter* could be a factor that contributes for obtaining the class-distribution, and also it can help to determine the knowledge of each of the chapters. In this study, *Fuzzy Logic* is used as a technique of *soft computing* to evaluate the students' performance in a particular subject. Here a set of questionnaires was prepared with the discussion from subject experts. Through this paper it can be concluded that this system is very much useful in order to analyse the performance of a student in a particular subject.

12. Discussion

Through this paper it can be concluded that this system is very much useful in order to analyse the performance of a student in a particular subject. This methodology can also be applied to those students that are under the performance category of 'poor' or 'very poor'. In order to improve the students' academic result, analysis of performance of each of the students in a particular subject is very much important. So, every academic institution can apply this methodology to analyze student's performance in their subject. In this study the experiments are carried out using *Matlab fuzzy toolbox* on *Windows 10 platform*. The proposed fuzzy model was tested with the performance data from the class x mathematics text book comprising all the chapters. Here a set of questionnaires was prepared with the discussion from subject experts. To investigate the students' attitude towards learning mathematics in class x standard, using the combination of the techniques of *Fuzzy Logic and artificial intelligence,* and to develop an *Internet Based Performance Evaluator* is the future research.

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