Automatically Constructing Grade Membership Functions for Strict-Type Grade and Lenient-Type Grade as Per the Evaluator's Degree of Strictness and Leniency

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Abstract— This paper presents the solution for the problems which arise because of subjective judgment of teachers. Broadly evaluators can be classified into three category namely strict type, lenient type and normal type. Evaluators can be strict or lenient but their degree of strictness and leniency can vary from evaluator to evaluator. Evaluator can be strict but one evaluator may be relatively more or less strict than other. Similarly it is applicable for lenient evaluator. When one evaluator is relatively more strict or lenient than other evaluator, how can be the marks inferred by all strict and all lenient teachers can be of one type? This paper addresses the solution to this problem by transforming marks awarded by them as per their degree of strictness and leniency into their respective approximately normal marks.

Index Terms Student's Evaluation, Fuzzy grading system, Fuzzy Logic, Fuzzy Reasoning, Fuzzy rules, Grade Membership Functions, Interpolation techniques.

1 INTRODUCTION

IN a search of finding more and more better method for student evaluation, many researchers have started using fuzzy logic in education grading and evaluation system. They use fuzzy approach to make student evaluation system more fair. Biswas [2] highlighted the importance of evaluation in education system by pointing "The chief aim of education institutions should be to provide students with the evaluation reports regarding their test/examination as sufficient as possible with unavoidable error as small as possible so as to make evaluation system more transparent and fairer to students". He proposed two methods fuzzy evaluation method (fem) and generalized fuzzy evaluation method (gfem). In the paper "Fuzzy Grading System" [16] uses fuzzy grading system which utilizes students' and instructor's performance measures in order to modify a set of collectively approved, a priori fuzzy grades, so as to produce a "fair" mark distribution. Chen and Lee [3] presented methods which removes drawbacks of Biswas's method. Their method performs calculation in much faster manner and does not required to use complicated matching operations. Later on [9] proposed method for evaluating students' answerscripts using fuzzy numbers associ
ated with degree of confidence. They have considered degree of confidence of evaluator when awarding satisfaction level to questions of student answerscripts. They have also introduces the concept of optimism index of evaluator. A novel method proposed by [22], give solution for finding the optimism index of evaluator more accurately. Three- node fuzzy structure was proposed by [15]. Their method considers the combined effect of difficulty, importance and complexity. Saleh and Kim [4] modified the method proposed by [15] and used max-min composition and COG method for defuzzification and kept the equal impact of each input on output. [12] Proposed a method for automatically generating the weights for various attributes like "accuracy rate", "time rate" , "difficulty", "complexity", "answer_cost" and "importance" with fuzzy reasoning capability. In most of the examinsation, time duration to solve per question is not specified but total time duration to attempt full question paper is specified. For such system [21] proposed two node structure. Ambiguity of question paper itself is considered by [1] and concept of vagueness is introduced as one of the evaluation criteria. Design of students' evaluation system is offered by [20].

Cheng et al [23] emphasized the key issue of subjective judgments of evaluators. They pointed out "Chief aim of educational grading systems should solve the subjective judging problem of teachers". They used grade membership functions to describe the characteristics of teachers. But they did not specify how to construct the membership functions of lenient-type grades, strict-type grades and normal-type grades, given by teachers, respectively, for students' evaluation. Bai and Chen [5] presented a method for automatically constructing the grade membership functions of lenient-type grades, strict-type grades and normal-type grades, given by teachers, respectively, for students' evaluation. On the basis of constructed grade membership functions, the system performs fuzzy reasoning to infer the scores of students. Method proposed by [5] overcomes the drawback of [23] and provides a method to evaluate students' answersheets in a smarter manner.

However, the method proposed by [5] has drawback that they did not consider the fact that the level of strictness and the level of leniency of every examiner may be different. Evaluator can be strict but one evaluator may be relatively more or less strict than other. In the same way it is applicable for lenient evaluator. One strict evaluator may be more or less strict than the other strict evaluator. Similarly, one lenient evaluator may be much more or less lenient than the other lenient evaluator. Evaluators can be strict or lenient but their degree of strictness and leniency can vary from evaluator to evaluator. When one evaluator is relatively more strict or lenient than other evalua-

tor, how can be the marks inferred by all strict and all lenient teachers can be of one type? This paper addresses the solution to this problem by transforming marks awarded by them as per their degree of strictness and leniency into their respective approximately normal marks. The proposed method constructs automatic grade membership functions for strict-type grade, lenient-type grade and normal-type grade as per the level or degree of strictness, leniency or normality (normalness) of evaluator/examiner/teacher.

In the paper[5], authors have assume that there is a strict-type teacher who have awarded the grade "36" to the answersheet of a student, then based on grade membership function of strict type teacher, transformation of strict type grade marks 36 into normal type grade of student's answesheet is 49. But, we emphasis that as per degree or level of strictness of examiner marks should have been converted and not that all strict type examiners' marks should be converted into same one type. If examiner is less strict than marks should have transformed accordingly and if examiner is stricter than others strict type examiners then the awarded grade marks should have transform accordingly.

The rest of paper is organized as follows. In section 2, we briefly review Bai and Chen [5] method of automatically constructing grade membership functions for strict-type grade, lenient-type grade and normal type grade for students' evaluation. In Section 3, we presented a method for automatically constructing grade membership functions for strict-type grade and lenient-type grade as per the degree of evaluator's Strictness and Leniency. Experimental results are shown and discussed in section 4. The conclusion of the proposed method is mentioned in section 5.

2 Review of Bai and Chen's Method of Automatically Constructing Grade Membership

In this section , we briefly reviews the method proposed by Bai and Chen[5] for automatically constructing grade membership functions for strict-type grade, lenient-type grade and normal type grade for students' evaluation. This method is helpful in finding the type of examiner i.e. lenient, strict or normal. This method is helpful when there are 'n' examiners for the assessment of 'm' answersheets. Ask the 'n' examiners to do the assessment of 'm' students' ansersheets. Here all 'm' common answersheets will be assessed by all 'n' teachers. Store the marks given by 'n' examiner for 'm' numbers of answerscripts(i.e. students) is shown below in matrix format.

Let E_i be the answerscript of the i th student, where $1 \leq i \leq m$. Assume that there are 'n' teachers T_1, T_2 , … T_n to grade the answerscripts, then we can get a grade matrix G, shown as follows:

$$G = \begin{array}{c} \\ E_1 \\ E_2 \\ \vdots \\ E_m \end{array} \begin{array}{c} \begin{array}{cccc} T_1 & T_2 & \cdots & T_n \end{array} \\ \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} \end{array}$$

The proposed method for constructing the grade membership functions of strict-type grades, lenient-type grades and normal-type grades of fuzzy rules, respectively, is now presented as follows:

Step 1: For each answerscript E_i, calculate its temporary average grade TAvgE_i,

$$\text{TAvg}E_i = \frac{\sum_{j=1}^{n} g_{ij}}{n} \quad \ldots\ldots\ldots\ldots (1)$$

Where $g_{ij} \in [0, 100]$, n denotes the number of teachers, m the number of answerscripts, $1 \leq i \leq m$ and $1 \leq j \leq n$.

Step 2: Calculate the distance d_{ij} between each grade g_{ij} and TAvgE_i where $d_{ij} = |\ \text{TAvg}E_i - g_{ij}\ |$, to get the distance matrix D, where $1 \leq i \leq m$, and $1 \leq j \leq n$. For each answerscript E_i, where $1 \leq i \leq m$, select the top 40% of the teachers who have higher distance to be the ''outlier'', where $1 \leq i \leq m$, and $1 \leq j \leq n$. The teacher who is an outlier and whose awarded grade is smaller than TAvgE_i will be classified into the class of strict- type teachers; the teacher who is an outlier and whose awarded grade is larger than TAvgE_i will be classified into the class of lenient-type teachers, where $1 \leq i \leq m$. Otherwise, the teacher is classified into the class of normal-type teachers.

Step 3: For each answerscript E_i, where $1 \leq i \leq m$, count the number j of strict-type teachers $T_{L1}, T_{L2}, \ldots\ldots T_{Lj}$ and count the number k of lenient-type teachers $T_{H1}, T_{H2}, \ldots\ldots T_{Hk}$. Then, for each answerscript E_i, where $1 \leq i \leq m$, calculate the average grade g_{Li} of strict-type teachers and calculate the average grade g_{Hi} of lenient type teachers, respectively, where

$$g_{Li} = \frac{\sum_{p=1}^{j} L_{ip}}{j} \quad , \ldots\ldots\ldots\ldots\ldots (2)$$

$$g_{Hi}=\frac{\sum_{q=1}^{k} H_{iq}}{j} \quad \text{,……. (3)}$$

L_{ip} denotes the grade of the answerscript E_i graded by strict-type teacher T_{Lp}, H_{iq} denotes the grade of the answerscript E_i graded by lenient-type teacher T_{Hq}, $1 \le p \le j$, and $1 \le q \le k$.

For each answerscript E_i, where $1 \le i \le m$, if $j > k$, , then it means that the number of teachers in the class of strict-type teachers is larger than the number of teachers in the class of lenient-type teachers and then apply Eq. (4) to get the more appropriate grade AvgE_i. If $k > j$, then it means that the number of teachers in the class of lenient type teachers is larger than the number of teachers in the class of strict-type teachers and then apply Eq. (4) to get the more appropriate grade AvgE_i. Otherwise (i.e., $j = k$), it means that the number of teachers in the class of lenient-type teachers is equal to the number of teachers in the class of strict-type teachers, and AvgE_i is equal to TAvgE_i, shown as follows:

$$\text{Avg}E_i = \begin{cases} \text{TAvg}E_i + \frac{(j-k)\times 0.5\times(g_{in}-g_{il})}{n}, & \text{if } j > k \\ \text{TAvg}E_i + \frac{(-(k-j)\times 0.5\times(g_{in}-g_{il})}{n}, & \text{if } k > j \\ \text{TAvg}E_i, & \text{if } k = j \end{cases} \quad \text{…….. (4)}$$

Then, calculate the total average strict-type grade $AvgG_L$ of g_{Li}, calculate the total average normal-type grade $AvgG_N$ of $AvgE_i$ and calculate the total average lenient-type grade $AvgG_H$ of g_{Hi}, respectively, where

$$\text{AvgG}_\text{L} = \frac{\sum_{i=1}^{m} g_{Li}}{m} \quad \text{…….. (5)}$$

$$AvgG_N = \frac{\sum_{i=1}^{m} \text{Avg}E_i}{m} \quad \text{…….. (6)}$$

$$AvgG_H = \frac{\sum_{i=1}^{m} g_{Hi}}{m} \quad \text{…… (7)}$$

Step 4: Use the interpolation techniques to get the most appropriate relational function between g_{Li} and AvgE_i and to get the most appropriate relational function between g_{Hi} and $AvgE_i$ respectively, where $1 \le i \le m$. For simplicity, we use a concave-downward curve through the points (0, 0), (100, 100) and (50 + $AvgG_L$ - $AvgG_N$, 50) to fit the relational function between g_{Li} and $AvgE_i$, where (0, 0), (100,100) and (50 + $AvgG_L$ - $AvgG_N$, 50) are called the starting point, the ending point and the central point of the concave downward curve, respectively, $1 \le i \le m$, and m is the number of students' answerscripts. Here use a concave-upward curve through the points (0, 0), (100, 100) and (50 +$AvgG_H$ - $AvgG_N$, 50) to fit the relational function between g_{Hi} and AvgE_i, where (0, 0), (100, 100) and (50 + $AvgG_H$ - $AvgG_N$, 50) are called the starting point, the ending point and the central point of the concave-upward curve, respectively, $1 \le i \le m$, and m is the number of students' answerscripts.

Step 5: Transform the values of the Y axis into the values between zero and one (i.e., divide each value in the Y axis by 100).

3 Proposed Method for Constructing Automatic Grade Membership Fuctions Teacher-wise

In this section, we present a method for transforming marks teacher-wise as per the level of strictness and leniency. Proposed method will construct the automatic grade membership function for every teacher according to the grades awarded by them. This method will construct the grade membership function as per the degree of evaluator's strictness, leniency or normalness. Following are the steps to construct the grade membership functions teacher-wise:

Step 1:
Select 'm' number of students' answersheets randomly as sample answersheets (for example three, five, seven etc.). Take the photo copies of these selected 'm' answersheet 'n' times, as we have 'n' number of examiners/evaluators/teachers for assessment. Now photocopies of these selected 'm' numbers of answersheets should be given to 'n' number of examiners, who will be doing the assessment of these answersheets and will award marks to each answersheets as per their judgment. Now, find the average of marks given by them to each answersheets by using formula (8),

$$AvgA_i = \frac{\sum_{j=1}^{n} g_{ij}}{n},\ i = 1..m \text{ and } j = 1..n, \quad \text{… (8)}$$

Step 2:
Next step is finding the level or degree of strictness, leniency or normalness of examiner with respect to other examiners. Calculate the average marks given by each 'n' examiner to 'm' answersheets by using formula (9),

$$AvgT_j = \frac{\sum_{i=1}^{m} g_{ij}}{m},\ i = 1..m \text{ and } j = 1..n, \text{ … (9)}$$

To have more correctness and validness in deciding the category of examiner, find the average of average marks got to 'm' students' answersheets by using the formula (10).

$$AvgAvg = \frac{\sum_{i=1}^{m} AvgA_i}{m}, \text{ …. (10)}$$

Step 3:

Now we want to find the degree or level of strictness or leniency of examiner. To do this calculate the difference between average marks awarded by each examiners to all the answersheet and average of average marks got to all answersheets i.e. between $AvgT_j$ and $AvgAvg$ using formula (11).

$$D_j = AvgT_j - AvgAvg\ , j = 1..n\ , \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Negative difference (D_j) is the indication of examiner belongs to strict category of examiners. But, if difference (D_j) of examiner is positive then examiner belongs to lenient category of examiners. If negative difference value is more than the other examiners who are having negative difference then the examiner is stricter than other strict types of examiners. Higher the value of negative difference more is the degree of strictness and lower the value of negative difference lesser is the degree of strictness of examiners. Similarly, if positive difference value is more than the other examiners who are having positive difference then the examiner is more lenient than other lenient types of examiners. Higher the value of positive difference more is the degree of leniency and lower the value of positive difference lesser is the degree of leniency of examiners. Normal type examiner will have difference value zero or a very small value of either positive or negative difference, that indicates normalness of examiners and examiner belongs to normal category.

Step 4:

Next step is to construct the grade membership functions teacher-wise. To construct the grade membership we have use interpolation technique. To get the most appropriate relation between average marks given by each teacher($AvgT_j$) and average of average($AvgAvg$) respectively, where $1 \leq j \leq n$. Concave-downward curve will get generated for lenient type teacher and concave-upward curve will get generated for strict type of teacher. For simplicity and also to fit the relation, we use points (0, 0), (100, 100) and (50 + D_j , 50) where D_j is $AvgT_j$ - $AvgAvg$, *here* $1 \leq j \leq n$. Points (0, 0), (100, 100) and (50 + D_j , 50) are called the starting point, the ending point and the central point of the concave-downward or concave–upward curve.

Step 5:

To **t**ransform the values of the Y axis into the values between zero and one, divide each value in the Y axis by 100. We can get the grade membership functions of lenient-type grade, strict-type grade and normal-type grade as per the degree of strictness, leniency and normalness of examiners.

Step 6:

Infer Strict-type and Lenient-type marks to normal marks using grade membership function.

Note: If the difference value is small, either positive or negative, then examiner will almost belong to normal-type category. Generations of curve of such types of examiners can be omitted as we may not be transforming marks awarded by these examiners as these examiners already belongs to almost normal category.

4 Experimental Results and Discussions

In this section, we have assumed the example which is used in [5]. This example will be helpful for comparison purpose and will also be helpful in illustrating the process of constructing teacher-wise grade membership functions.

Example: Assume that number of Teachers/Examiners is ten and number of sample ansersheets chosen randomly is five as shown in Table 1, which represents marks of five students' answersheets A1, A2… A5 and assessment have done by ten Teachers T1, T2 … T10 answersheets.

TABLE 1
Marks of Students' Answersheets

Marks	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}
A_1	18	23	26	30	33	38	42	43	46	48
A_2	31	34	35	39	42	42	51	53	59	61
A_3	46	53	65	69	71	71	71	72	74	75
A_4	68	69	74	75	80	82	84	88	92	96
A_5	80	84	84	91	91	93	95	100	100	100

Step 1:

To find the average of marks awarded to each answersheet by using formula (8) is shown below and in Table 2,

$AvgA_i$= [34.7000 44.7000 66.7000 80.8000 91.8000]'

TABLE 2
Average Reference Marks for Each Student's Answersheet

Students Answersheet	A_1	A_2	A_3	A_4	A_5
$AvgA_i$	34.7	44.7	66.7	80.8	91.8

Step 2:

Using formula (9) find the average marks given by 'n' examiners to 'm' answersheets is shown in Table 3.

TABLE 3
Average Reference Marks for Each Teacher Given to Answersheets

Teacher	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
$AvgT_j$	48.60	52.60	56.80	60.80	63.40	65.20	68.60	71.20	74.20	76.00

To evaluate average of average marks got to each answersheet, formula (10) is used.

***AvgAvg*=63.74**

Difference of each examiner is calculate using formula (11) and is shown in Table 4.

TABLE 4
Difference of Each Teacher's Average Marks From AvgAvg

Teacher	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
D_j	-15.14	-11.14	-6.94	-2.94	-0.34	1.46	4.86	7.46	10.46	12.26

Step 4:

To constructing grade membership functions teacher-wise, interpolation techniques is used to plot concave-upward curve and concave-downward carve by using points (0, 0), (100, 100) and (50 + D_j , 50) .

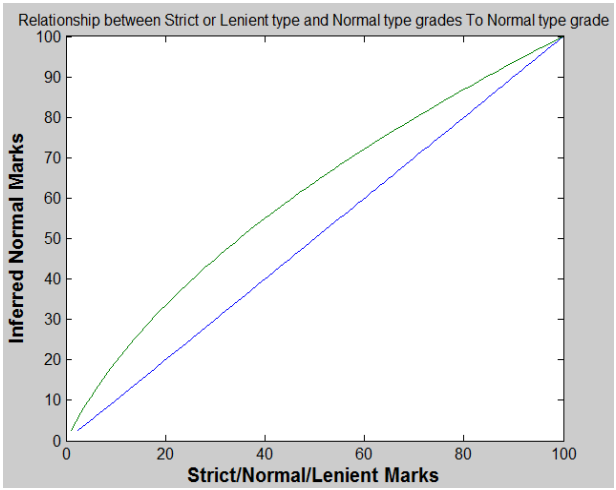

Fig. 1. Teacher 1 (Strict)

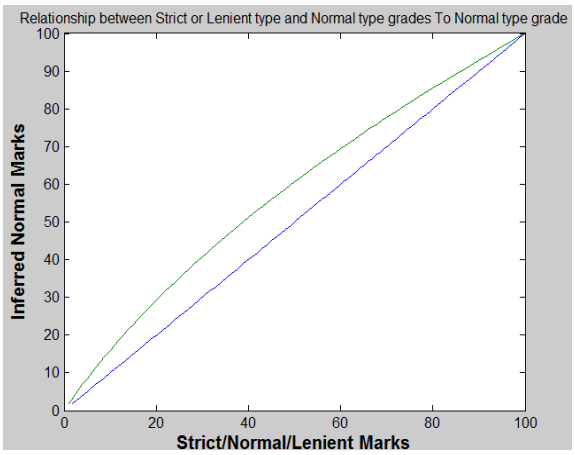

Fig. 2. Teacher 2 (Strict)

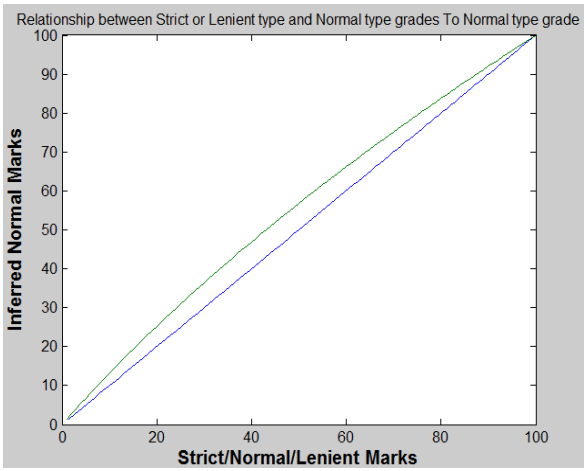

Fig. 3. Teacher 3 (Strict)

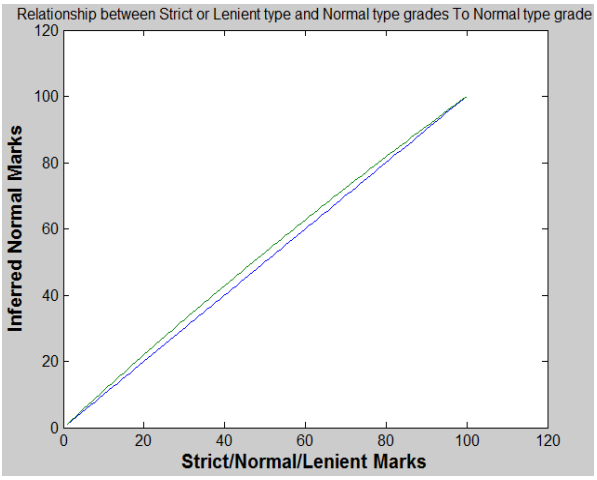

Fig. 4. Teacher 4 (Almost Normal)

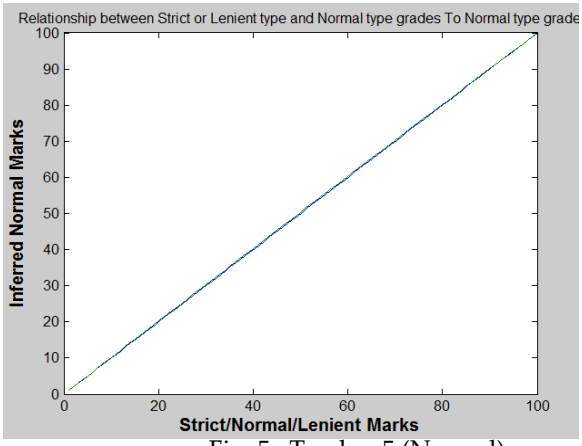

Fig. 5. Teacher 5 (Normal)

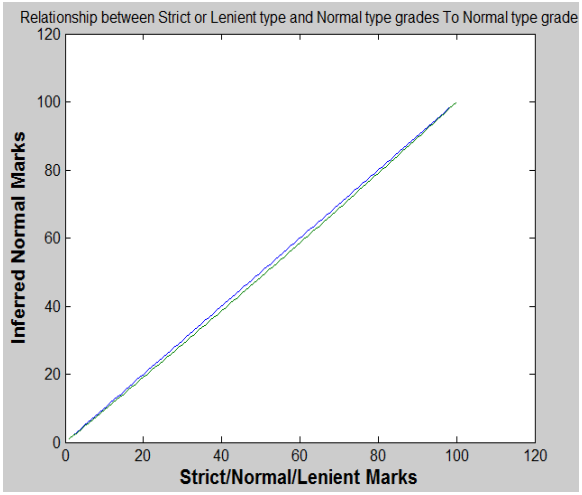

Fig. 6. Teacher 6 (Almost Normal)

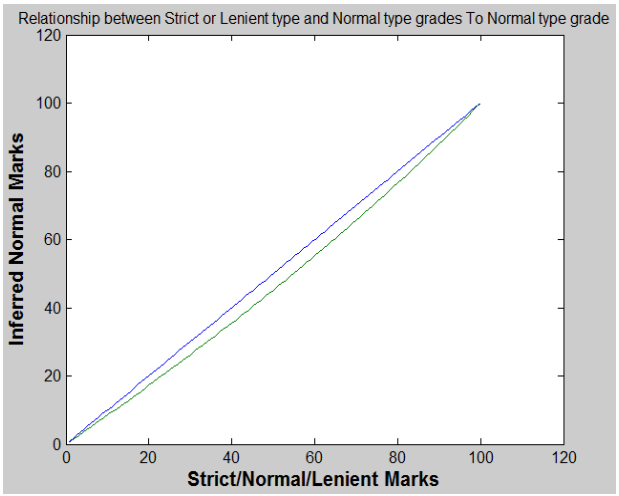

Fig. 7. Teacher 7 (Almost Normal)

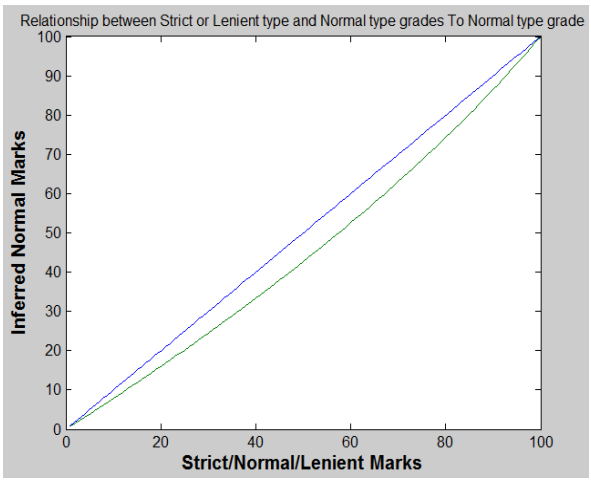

Fig. 8. Teacher 8 (Lenient)

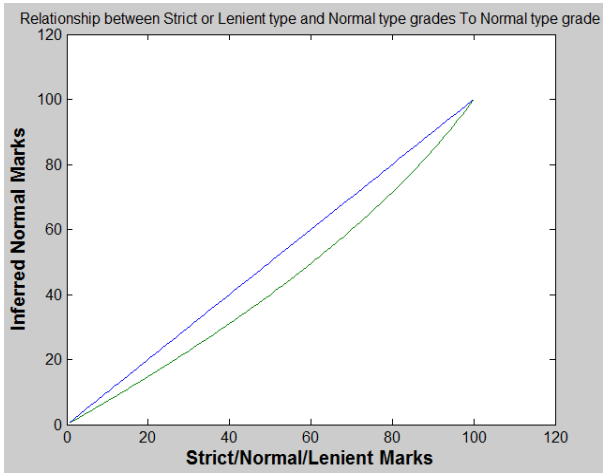

Fig. 9. Teacher 9 (Lenient)

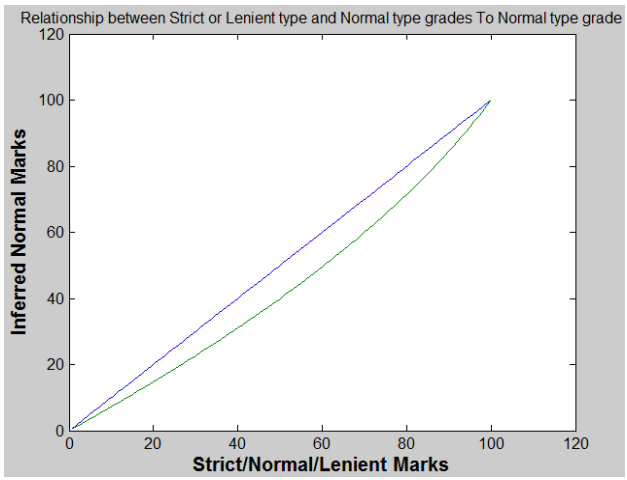

Fig. 10. Teacher 10 (Lenient)

Step 5:

Transform the values of Y-axis for every teacher. Table 5 shows the assigned grade marks (A) and transformed grade marks (T) of Teacher 1.

TABLE 5
Transformation of Grade Marks of Teacher-1

A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
1	2	11	21	21	35	31	46	41	56	51	65	61	73	71	81	81	88	91	94
2	5	12	23	22	36	32	47	42	57	52	66	62	74	72	81	82	88	92	95
3	7	13	24	23	37	33	48	43	58	53	66	63	75	73	82	83	89	93	96
4	9	14	26	24	38	34	49	44	59	54	67	64	75	74	83	84	90	94	96
5	11	15	27	25	39	35	50	45	60	55	68	65	76	75	83	85	90	95	97
6	13	16	28	26	41	36	51	46	60	56	69	66	77	75	84	86	91	96	97
7	15	17	30	27	42	37	52	47	61	57	70	67	78	77	85	87	92	97	98
8	16	18	31	28	43	38	53	48	62	58	71	68	78	78	86	88	92	98	99
9	18	19	32	29	44	39	54	49	63	59	71	69	79	79	86	89	93	99	99
10	20	20	33	30	45	40	55	50	64	60	72	70	80	80	87	90	94	100	100

*A → Assigned Grade Marks T→ Transformed Grade Marks

Step 6:

Infer the marks teacher-wise for a given grade. Table 6 shows that when 36 grade marks awarded by different teachers, transformation of marks take place according to teacher's/examiner's level of strictness and leniency. Normal-type teacher's marks remain same. Teachers who's difference (D_j) is in the range of ± 5 will belongs to almost normal category (For more accuracy value of almost- normal- type can be even in the range of ± 3 or even can be kept less). The teachers who belong to almost normal category their inferred marks are nearly equal to the assigned grade marks.

TABLE 6
Conversion of Marks **36** as Per Teacher-Wise Grade Membership Function

Teacher	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Inferred Marks	51	47	43	39	36	35	32	30	28	26

Teachers T1, T2 and T3 belong to strict type category so according to their relative degree of strictness, awared grade-marks 36 are inferred to 51, 47 and 43 respectively and not that all strict teachers' marks transform into same grade marks. Similarly, it is applicable to lenient teachers' grade marks will be inferred (reduced) accordingly.

Fig 1 shows Teacher-1 is of strict-type teacher, so inferred grade (Marks) should be more than the assigned grade marks and as per examiner's level of strictness. Similarly, on the basis of results shown in figures 2 to 10 description for the same is mention below:

Fig 2 shows Teacher-2 belongs to strict-type teacher, so inferred grade (Marks) should be more than the assigned grade marks and as per the examiner's degree of strictness.

Fig 3 shows Teacher-3 belongs to strict-type teacher, so inferred grade (Marks) should be more than the assigned grade marks and as per the examiner's degree of strictness.

Fig 4 shows Teacher-4 belongs to almost normal-type teacher, so inferred grade (Marks) should be approximately near to normal type grade.

Fig 5 shows Teacher-5 is of normal-type teacher and inferred grade (Marks) should be equal to the grade marks assigned by examiner/teacher.

Fig 6 shows Teacher-6 belongs to almost normal-type teacher, so inferred grade (Marks) should be approximately near to normal type grade.

Fig 7 shows Teacher-7 belongs to almost normal-type teacher, so inferred grade (Marks) should be approximately near to normal type grade.

Fig 8 shows Teacher-8 belongs to lenient-type teacher, so inferred grade (Marks) should be less than the assigned grade marks and as per the examiner's degree of leniency.

Fig 9 shows Teacher-9 belongs to lenient-type teacher, so inferred grade (Marks) should be less than the assigned grade marks and as per the examiner's degree of leniency.

Fig 10 shows Teacher-10 belongs to lenient-type teacher, so inferred grade (Marks) should be less than the assigned grade marks and as per the examiner's degree of leniency.

5 Conclusion

Student evaluation is the key aspect of education system. Fair evaluation gives motivation to students to work harder and perform better. Evaluation result is the receipt or reward of student's wisdom. Unfair evaluation may make students disheartened and they will find it difficult to have faith in education system. This paper makes an attempt to solve the problem which arises due to subjective judgment of evaluators. As per the evaluator level of strictness and leniency, the proposed system infers the marks awarded by them into approximately normal marks.

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