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Evaluation of Teaching Performance with Outliers Data using Fuzzy Approach

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Abstract

Both ratings and weight aspects have recently received great consideration in teaching performance evaluation. Unfortunately, in some cases, the trend of adopting merely the rating aspect has created concern as it can lead to questionable outcome. Besides that, the existence of outliers in the data will also affect the evaluations’ results. Evaluating teaching performance is also not an easy task as it involves human decision making which is imprecise, vague and uncertain. In this paper, the fuzzy evaluation method with fuzzy Jaccard ranking index is applied in evaluating teaching performance at one of the public universities in the East Coast of Malaysia. The outliers data which are detected by using the standard score concept were trimmed off and thus had minimized the variation within the data. Findings conclude that teaching is the key factor in evaluating the teaching performance. The proposed approach gives a promising prospect in teaching performance evaluation where it provides a more reasonable and intelligent evaluation with accurate results.

Keywords: Teaching evaluation; Fuzzy evaluation; Jaccard ranking index; Outliers data

1. Introduction

According to Chen and Chen (2010), higher education is the foundation for fostering high technology expert, the key factor in increasing national quality and the main way to upgrade a nation’s competitive status. The deep reform of higher education such as large scale expansion of students’ enrolment, vigorous promotion for educators and the existence of many new higher education institutions, on the other hand, had created many issues including the quality of teaching which is particularly prominent. Thus, it is of great importance to evaluate teaching performance.

Many studies have proved that students’ evaluation is an effective tool in evaluating teaching performance which has helped educators in improving their teaching performance and therefore, has also helped students’ learning as well. According to Hon et al. (1996), in developing a performance evaluation of multiple criteria cases, four aspects must be considered which are i) the interrelationship of different criteria, ii) the ratings of the criteria of each alternative, iii) the weights of each criteria, and, iv) the aggregation of each rating with its weight. Most cases of

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performance evaluation consider both the ratings and weight aspects, but in some cases only the ratings part was considered thus leading to a questionable outcome. Besides that, the existence of outliers in the data will affect the evaluations’ results and it needs to be catered accordingly. The performance evaluation is also not an easy task as it involves human decision making which is imprecise, vague and uncertain.

In recent years, a number of researchers have focused on solving teaching performance evaluation issues by using fuzzy set theory. Hon et al. (1996) presented a method for teaching performance evaluation based on fuzzy max-min paired elimination and gradient eigen-vector methods. Their method considered the inconsistency in assigning the weights and ratings given by different decision makers and has led to accurate result for the performance evaluation in higher education systems. Yan and Fan (2009) proposed fuzzy analytic hierarchy process and fuzzy synthetic model in evaluating the teaching performance at one of the universities in China where their method shows a good application of fuzzy theory in evaluating teaching performance. Wei et al. (2009) established a teaching evaluation model based on fuzzy comprehensive evaluation which can evaluate the network teaching fairly and reasonably. Chen and Chen (2010) developed fuzzy analytic network process for performance appraisal system for three universities in Taiwan. Their method has provided fair and consistent performance evaluation as it considered inconsistencies among different types of universities involved and also inconsistencies in the measurement criteria.

Wang and Chen (2008) established a fuzzy evaluation model for high school teachers. The method evaluated the performance of alternatives and the weight of criteria as crisp numbers with the total of related crisp numbers needing to equal to 100% which is cumbersome to the decision makers. Besides that, the method also trimmed off the data with the smallest and largest values which is similar to Lin and Chang’s (2008) approaches. According to Lin and Chang (2008), fuzzy assessment should not be influenced by the extreme data, but these extreme data do not necessarily become the outliers that will affect the results. Barnett and Lewis (1994) defined the outliers as the data having values which are very different from the data values of the majority of the cases in the data set. Thus, the fuzzy assessment presented in Lin and Chang’s (2008) and Wang and Chen’s (2008) study may not be precise as the data which were trimmed off might not be outliers. In order to solve the issues, Ramli and Mohamad (2009a) proposed an evaluation method which used fuzzy linguistic variables throughout the process and trimmed off the outliers based on the standard score concept. The use of fuzzy linguistic variables had provided a human orientated decision making process, while the standard score concept had minimized variations within the data and rendered Ramli and Mohamad’s (2009a) method more accurate compared to Wang and Chen’s (2008).

In this paper, Ramli and Mohamad’s (2009a) evaluation method is applied in evaluating the teaching performance at one of the public universities in the East Coast of Malaysia. The normal practices of the traditional evaluation only consider the students’ ratings and no consideration is given to the outliers’ data. To assign ranks, the Jaccard ranking index from Setnes and Cross (1997) which is capable of preserving the inheritance of fuzzy information is applied. The ranking method has been extended to all shapes of fuzzy numbers by Ramli and Mohamad (2009b) and has been shown improving some of the ranking indices such as in Cheng’s (1998), Yao and Wu’s (2000), Chu and Tsao’s (2002), Abbasbandy and Asady’s (2006), Asady and Zendehnam’s (2007), Chen and Chen’s (2007) and Wang and Lee’s (2008) in some situations. This paper is organized as follows: Section 2 presents basic definitions of fuzzy mathematics, while Sections 3 and 4 present the fuzzy evaluation method and fuzzy Jaccard ranking index respectively. The procedure for fuzzy evaluation is presented in Section 5. In Section 6, results and discussions are presented. Finally, conclusions are given in Section 7.

2. Preliminaries

In this section, some basic definitions of fuzzy sets and fuzzy numbers from Wang (1997) are briefly reviewed.

2.1 Fuzzy Sets

A fuzzy set \( \tilde{A} \) in a universe of discourse \( X = \{x_1, x_2, \ldots, x_n\} \) can be represented by

\[
\tilde{A} = \mu_{\tilde{A}}(x_1)/x_1 + \mu_{\tilde{A}}(x_2)/x_2 + \ldots + \mu_{\tilde{A}}(x_n)/x_n
\]

where \( \mu_{\tilde{A}} \) denotes the membership function of the fuzzy set \( \tilde{A} \) and \( \mu_{\tilde{A}}: X \to [0,1] \).
For $i = 1, 2, \ldots, n$, $\mu_{\tilde{A}}(x_i)$ denotes the grade of membership of $x_i$ to the fuzzy set $\tilde{A}$.

A fuzzy set $\tilde{A}$ in the universe of discourse $X$ is convex if and only if for all $x_1, x_2 \in X$,

\[ \mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)) \]

where $\lambda \in [0,1]$.

If there exists $x_i \in X$ such that $\mu_{\tilde{A}}(x_i) = 1$, then the fuzzy set $\tilde{A}$ is called a normal fuzzy set. For all $x \in X$, such that $\mu_{\tilde{A}}(x) \in (0,1)$, the fuzzy set $\tilde{A}$ is called a non-normal fuzzy set.

### 2.2 Fuzzy Numbers

A fuzzy number is a fuzzy subset in the universe discourse that is both convex and normal. The membership function of a fuzzy number $\tilde{A}$ can be defined as

\[
\mu_{\tilde{A}}(x) = \begin{cases} 
\frac{x - a}{b - a}, & a \leq x \leq b \\
1, & b \leq x \leq c \\
\frac{x - c}{d - c}, & c \leq x \leq d \\
0, & \text{otherwise}
\end{cases}
\]

where $f_L^L$ is the left membership function that is increasing and $f_L^R : [a, b] \to [0,1]$. $f_R^R$ is the right membership function that is decreasing and $f_R^L : [a, b] \to [0,1]$. If $f_L^L$ and $f_R^R$ are linear and continuous, then $\tilde{A}$ is a trapezoidal fuzzy number denoted by $(a, b, c, d)$. Triangular fuzzy number which is a special case of trapezoidal fuzzy number with $b = c$ is denoted as $(a, b, d)$ and is shown in Figure 1.

![Figure 1: A triangular fuzzy number $\tilde{A} = (a, b, d)$](image)

### 3. Fuzzy Evaluation Method

Fuzzy evaluation method from Ramli and Mohamad (2009a) which used the fuzzy linguistic variables throughout the procedure and applied aggregated fuzzy numbers based on the standard score concept is presented as follows. Table 1 shows the linguistic variables used in evaluating the importance levels of each criterion and satisfaction levels of each sub-criterion.

| Linguistic Variable | Importance Level | Satisfaction Level |
|---------------------|------------------|--------------------|
| Very Low           | 1                | 0                  |
| Low                | 2                | 1                  |
| Medium             | 3                | 2                  |
| High               | 4                | 3                  |
| Very High          | 5                | 4                  |

Table 1: Linguistic variables for the importance level and satisfaction level
Step 1: For K decision maker, the fuzzy weight $\tilde{w}_j$ of each criterion is calculated by using aggregated fuzzy assessment. The extreme values which are detected based on the standardized score of ±3 or beyond for $N > 80$ and ±2.5 or beyond for $N \leq 80$ are trimmed off.

The importance weight $\tilde{w}_j$ of each criterion is defined as

$$\tilde{w}_j = \frac{1}{K - s} \left[ \sum_{k=1}^{K} \tilde{w}_j^k - \sum_{k=1}^{s} \text{extreme} \left\{ \tilde{w}_j^k \right\} \right]$$

where $\tilde{w}_j^k$ is the importance weight of the k-th decision maker and s is the number of extreme values. The fuzzy weighted vector for three criteria can be represented as $W = \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \tilde{w}_3 \end{bmatrix}$.

Step 2: The fuzzy grade $\tilde{g}_{ij}$ of each sub-criterion of each alternative can be calculated using aggregated fuzzy assessment. Similar with Step 1, the extreme linguistic judgment values of the decision maker for evaluating the i-th alternative with respect to the j-th criterion are trimmed off. Therefore, the fuzzy grade $\tilde{g}_{ij}$ of each sub-criterion of each alternative is defined as

$$\tilde{g}_{ij} = \frac{1}{K - s} \left[ \sum_{k=1}^{K} \tilde{x}_{ij}^k - \sum_{k=1}^{s} \text{extreme} \left\{ \tilde{x}_{ij}^k \right\} \right]$$

where $\tilde{x}_{ij}^k$ is the ratings of the k-th decision maker and s is the number of extreme values.

Step 3: Build the fuzzy grade matrix $\tilde{G}$ defined as

$$\tilde{G} = A \begin{bmatrix} X_1 & X_2 & \cdots & X_k \\ \tilde{g}_{11} & \tilde{g}_{12} & \cdots & \tilde{g}_{1k} \\ \tilde{g}_{21} & \tilde{g}_{22} & \cdots & \tilde{g}_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{g}_{n1} & \tilde{g}_{n2} & \cdots & \tilde{g}_{nk} \end{bmatrix}$$

where $\tilde{g}_{ij}$ denotes the fuzzy grade of the i-th alternative $A_i$ with respect to the j-th criterion $X_j$, n denotes the number of alternatives and k denotes the number of criteria.

Step 4: Calculate the total fuzzy grade vector $\tilde{R}$ with

$$\tilde{R} = \tilde{G} \otimes \tilde{W} = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1k} \\ g_{21} & g_{22} & \cdots & g_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ g_{n1} & g_{n2} & \cdots & g_{nk} \end{bmatrix} \otimes \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_k \end{bmatrix} = \begin{bmatrix} \tilde{R}_1 \\ \tilde{R}_2 \\ \vdots \\ \tilde{R}_k \end{bmatrix}$$

where $\tilde{R}_i$ denotes the total fuzzy grade of the i-th alternative $A_i$ and $1 \leq i \leq n$.

Further, the ranking order of $\tilde{R}_i$ is calculated. In this study, the fuzzy Jaccard ranking index from Setnes and Cross (1997) is applied.
4. Fuzzy Jaccard Ranking Index

Fuzzy Jaccard ranking index by Setnes and Cross (1997) is presented as follows:

**Step 1:** For each pair of fuzzy numbers $A_i$ and $A_j$ where $i, j = 1, 2, K, n$, find the fuzzy minimum and fuzzy maximum between $A_i$ and $A_j$.

**Step 2:** Calculate the evidences of $E(A_i \geq A_j)$, $E(A_j \leq A_i)$, $E(A_i \geq A_j)$ and $E(A_j \leq A_i)$ which are defined based on fuzzy Jaccard index as $E(A_i \geq A_j) = S_j \left( \text{MAX}(A_i, A_j), A_j \right)$, $E(A_j \leq A_i) = S_j \left( \text{MIN}(A_i, A_j), A_i \right)$, where $S_j(A_i, A_j) = \frac{A_i \cap A_j}{A_i \cup A_j}$. For simplification, $C_{ij}$ and $c_{ij}$ are used to represent $E(A_i \geq A_j)$ and $E(A_j \leq A_i)$, respectively. Likewise, $C_{ji}$ and $c_{ji}$ are used to denote $E(A_j \geq A_i)$ and $E(A_i \leq A_j)$ respectively.

**Step 3:** Calculate the total evidences $E_{total}(A_i \geq A_j)$ and $E_{total}(A_j \geq A_i)$ which are defined based on the mean aggregation concept as

$$E_{total}(A_i \geq A_j) = \frac{C_{ij} + c_{ji}}{2}$$

and

$$E_{total}(A_j \geq A_i) = \frac{C_{ji} + c_{ij}}{2}.$$ 

$E_z(A_i, A_j)$ and $E_z(A_j, A_i)$ are used to replace $E_{total}(A_i \geq A_j)$ and $E_{total}(A_j \geq A_i)$, respectively.

**Step 4:** For two fuzzy numbers, compare the total evidences in Step 3 which will result the ranking of the two fuzzy numbers $A_i$ and $A_j$ as follows:

i. $A_i \phi A_j$ if and only if $E_z(A_i, A_j) > E_z(A_j, A_i)$.

ii. $A_i \pi A_j$ if and only if $E_z(A_i, A_j) < E_z(A_j, A_i)$.

iii. $A_i \approx A_j$ if and only if $E_z(A_i, A_j) = E_z(A_j, A_i)$.

**Step 5:** For $n$ fuzzy numbers with consistent pair wise ranking, do the total ordering. While for non-consistent pair wise ranking, develop $n \times n$ binary ranking relation $R_z(A_i, A_j)$ and a column vector $[O_j]$, defined as

$$R_z(A_i, A_j) = \begin{cases} 1, & E_z(A_i, A_j) > E_z(A_j, A_i) \\ 0, & \text{otherwise} \end{cases}$$

and

$$O_j = \sum_{j=1}^{n} R_z(A_i, A_j) \quad \text{for} \quad j = 1, 2, K, n.$$ 

The total ordering of the fuzzy numbers $A_i$ corresponds to the order of the elements $O_j$ in the column vector $[O_j]$.

5. Fuzzy Evaluation of Teaching Performance

The study was carried out in evaluating the teaching performance of six lecturers $A_1, A_2, A_3, A_4, A_5$ and $A_6$ at one of the public universities in the East Coast of Malaysia where the normal practices of the traditional evaluation only consider the students’ ratings. One hundred Mathematical Sciences students were involved in this study. Eleven
items of the standard questionnaire of that particular university are categorized into three basic criteria that are teaching, class management and professional and motivational attitude as shown in Table 2.

Two sets of fuzzy linguistic questionnaires consisting of the importance levels of each criterion and the satisfaction levels of each criterion were distributed among the students. The data were analyzed by using fuzzy evaluation method by Ramli and Mohamad (2009a).

| Criteria | Sub-criteria |
|----------|--------------|
| X₁ (teaching) | X₁₁: Preparation of delivering teaching materials.  
X₁₂: Knowledge ability in using teaching materials.  
X₁₃: Presenting well-organized teaching materials.  
X₁₄: Ability to keep students’ attention throughout the class. |
| X₂ (class management) | X₂₁: Giving opportunities for questions and discussions.  
X₂₂: Evaluating assignments, tests and quizzes fairly according to the standard of the course. |
| X₃ (professional and motivational attitude) | X₃₁: Always attending class.  
X₃₂: Coming to class on time.  
X₃₃: Showing interest and enthusiasm during teaching.  
X₃₄: Showing concern on students’ attendance.  
X₃₅: Treating students fairly. |

6. Results and Discussion

Based on the fuzzy evaluation method, we obtained the fuzzy weight \( \tilde{w} \), fuzzy grade matrix \( \tilde{G} \) and total fuzzy grade vector \( \tilde{R} \) as follows;

\[
W = \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \tilde{w}_3 \end{bmatrix} = \begin{bmatrix} (6.45, 9.18, 10) \\ (5.82, 8.45, 9.82) \\ (6.27, 8.91, 10) \end{bmatrix}, \quad \tilde{G} = \begin{bmatrix} A_1 \\ A_2 \\ A_3 \end{bmatrix} = \begin{bmatrix} (4.25, 6.75, 9.15) \\ (4.76, 7.32, 9.41) \\ (6.39, 19.77) \end{bmatrix}, \quad \tilde{R} = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \\ R_6 \end{bmatrix} = \begin{bmatrix} (87.42, 190.86, 277.18) \\ (91.48, 200.64, 280.43) \\ (112.18, 234.57, 288) \\ (103.43, 218.65, 287.62) \\ (115.95, 238.48, 294.66) \\ (109.49, 230.89, 286.52) \end{bmatrix}
\]

The fuzzy weight \( \tilde{w} \) indicates the importance of criteria given by the students. The students evaluate criteria \( X₁ \) (teaching) as the most important criterion, followed by \( X₃ \) (professional and motivational attitude) and \( X₂ \) (class management). This shows that teaching is the key factor in evaluating teaching performance followed by professional and motivational attitude, and class management. The fuzzy grade \( \tilde{G} \) indicates that for criteria \( X₁ \) (teaching), the students grade lecturer \( A_3 \) as the best, followed by \( A_5, A_6, A_4, A₂ \) and \( A₁ \). For criteria \( X₂ \) (class
management), the students evaluate lecturer $A_4$ as the best, followed by $A_5, A_1, A_3, A_6$ and $A_2$. While for criteria $X_3$ (professional and motivational attitude), the students rate lecturer $A_5$ as the best, followed by $A_3, A_6, A_2, A_4$ and $A_1$.

Furthermore, by using fuzzy Jaccard ranking index, we obtained the pair wise ranking results as in Table 3.

|       | $A_2$ | $A_3$ | $A_4$ | $A_5$ | $A_6$ |
|-------|-------|-------|-------|-------|-------|
| $A_1$ | $A_1 \pi A_2$ | $A_1 \pi A_3$ | $A_1 \pi A_4$ | $A_1 \pi A_5$ | $A_1 \pi A_6$ |
| $A_2$ | $A_2 \pi A_3$ | $A_2 \pi A_4$ | $A_2 \pi A_5$ | $A_2 \pi A_6$ | $A_2 \phi A_{1}$ |
| $A_3$ | $A_3 \phi A_4$ | $A_3 \pi A_5$ | $A_3 \phi A_6$ | $A_3 \phi A_{1}$ | $A_3 \phi A_{1}$ |
| $A_4$ | $A_4 \pi A_5$ | $A_4 \pi A_6$ | $A_4 \phi A_{1}$ | $A_4 \phi A_{1}$ | $A_4 \phi A_{1}$ |
| $A_5$ | $A_5 \phi A_6$ | $A_5 \phi A_{1}$ | $A_5 \phi A_{1}$ | $A_5 \phi A_{1}$ | $A_5 \phi A_{1}$ |

Since the pair wise ranking results are consistent, the total ordering can be done which produces $A_5 \phi A_3 \phi A_6 \phi A_4 \phi A_2 \phi A_1$. This means that the students evaluate lecturer $A_5$ as the best followed by $A_3, A_6, A_4, A_2$ and $A_1$, which is similar with the evaluation of teaching criteria $X_1$.

However, if data with the smallest and largest values were trimmed off as in Wang and Chen (2008), the total fuzzy grade vector becomes $\tilde{R} = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \\ R_6 \end{bmatrix} = \begin{bmatrix} (83.78, 183.91, 270.83) \\ (89.4, 196.68, 276.83) \\ (105.53, 223.88, 277.68) \\ (99.38, 211.24, 280.72) \\ (107.98, 225.28, 283.32) \\ (106.87, 226.61, 282.82) \end{bmatrix}$ and, produces the ranking result as $A_5 \phi A_3 \phi A_6 \phi A_4 \phi A_2 \phi A_1$. This type of evaluation grades lecturer $A_5$ as the best, followed by $A_6, A_3, A_4, A_2$ and $A_1$, which is slightly different from the result of trimmed data using the standard score concept. While the ranking result by the normal practices of the university’s evaluation using the mean value is $A_5 \approx A_6 \phi A_3 \phi A_4 \phi A_2 \phi A_1$, which cannot discriminate the ranking between lecturers $A_5$ and $A_6$.

Thus, the evaluation of teaching performance is affected by the way data were trimmed off. Nevertheless, this study provides a more accurate evaluation of teaching performance as the method used had minimized the variation within the data compared to Wang and Chen’s (2008).

7. Conclusion

Teaching performance evaluation is an effective tool in improving teaching performance. In this paper, a fuzzy evaluation method which considers both the ratings and weight aspects is applied in evaluating the teaching performance at one of the public universities in the East Coast of Malaysia. This study shows that the ranking of lecturers’ teaching performance is affected by the way outlier data were trimmed off. The outlier data were trimmed off by using the standard score concept which had minimized the variation within the data and makes this study more precise than Wang and Chen’s (2008) and Lin and Chang’s (2008). The fuzzy evaluation also has improved the evaluation of normal practices of the university and has provided a better result which can distinguish the ranking among alternatives. The findings show that teaching is the most important criterion in evaluating teaching performance, followed by professional and motivational attitude, and class management. The ranking of lecturer’s performance obtained from this study is also consistent with Ramli and Mohamad (2009a) which used the centroid ranking method. The best lecturer has the top ratings for almost all of the criteria with the highest ratings for teaching and professional and motivational attitude criteria. Thus, this study shows a promising prospect in teaching performance evaluation as it gives a more reasonable and intelligent evaluation with consistent and accurate results.
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