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Exploring the Hamming Distance Method with Shannon Entropy Concept: Measuring in Performance Appraisal

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ABSTRACT

Performance appraisal often been regards as one of essential process in determining the current performance of the employee. However, to identify the best performance of an employee is not an easy process. There are several aspects that need to be consider to ensure that the selection process are done in fair judgments with no existence of bias or error. Thus, the main purpose of this paper is to determine the best employee performance by using Hamming distance method with Shannon entropy concept. In this case, Shannon entropy concept is used to determine the criteria important plus fuzzy set theory is also incorporated to handle the uncertainty that exist. A real world data from an institute of local university in Malaysia is applied. Based from final results, a ranking of the alternatives is made and future research is suggested to improve the proposed method.

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INTRODUCTION

Performance appraisal can be used as an indicator in measuring the performance of the employee effectiveness and efficiency in an institution or organization (Aggarwal & Thakur, 2013). Eventually, it can be employed in performing some significance process for instance measuring the past performance of an employee, rewarding process and also predicting and creating the goal for future performance and development of an employee (Sapra, 2012). Since this process included multiple criteria that need to be evaluated, one solution is by applying multi-criteria decision making (MCDM) method. MCDM methods usually can be used in evaluating, selecting or ranking a finite set of available alternatives against multiple and conflicting criteria (Chang *et al*., 2013). Distance measure method is one of MCDM method that recognized for its proficiency and capability in measuring related distance measure exemplified by similarity and proximity. One of the well-known distance measure methods is Hamming distance method.

Hamming distance method (Hamming, 1950), can be used to calculate the difference between two sets or elements, for instance the distance between the extremes of the intervals in fuzzy set theory (Canós *et al*., 2011). Consequently, this method can be used in solving the decision making problem by determining the distance values between two elements which are the alternative and ideal alternative. In this case, the ideal alternative is a virtual alternative created by the decision makers that will be used as an indicator of the alternative performance. Usually, the ideal alternative will possessed the highest marks for each criterion. In this paper, the ideal alternative marks will be assessed based on the decision makers' preference. Through the distance values, the order and ranking of the alternatives is made. This ranking is useful for the selection of the best alternative in which the alternative with the less distance value will be the one to be selected.

Apart from Hamming distance method, the application of fuzzy set theory (Zadeh, 1965) also embedded with problem solving capabilities. The use of this theory are relevant with this cases, as the decision makers often encounter with inconsistencies of human judgment during the evaluation process especially when involving the qualitative criteria such as leadership, personality and creativity that usually define in subjective and vagueness data. Plus, in certain condition, the information that exists is unobtainable, unquantifiable, incompleted and in partial ignorance condition which hinder the evaluation process (Yeh & Deng, 1997). Therefore, the use of fuzzy set theory is clearly matched to solve this problem.

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In certain circumstances, the ranking of the alternatives cannot properly be made due to the same distance values obtain by two or more alternatives which resulted, them to share the same ranking place. Alternatively, to solve this problem, the decision maker can prioritize the criteria by assigning relative weight for each one of them. The criteria with the highest weight show that this criterion plays an important role in deciding the best alternative. Shannon entropy concept is one of numerous methods that can be used to calculate the criteria weight. Shannon's entropy concept (Shannon & Weaver, 1947) is known as a general measure of uncertainty in information expressed in terms of probability theory (Wang *et al*., 2007). This concept can be used in measuring the relative differences intensities of criteria in representing the average intrinsic information transmitted to the decision makers (Zeleny, 1996). Meanwhile, entropy weight is as a parameter that can be used to identify the differences between the alternatives with respect to a certain criteria (Wang & Lee, 2009).

The main objective of this paper is to solve the performance appraisal process using the Hamming distance method with Shannon entropy concept. Inspired by the previous algorithm proposed by Canós *et al*. (2011), the researchers extended and improved the existing algorithm with the addition of entropy based weight. Linguistic terms captured in a form of triangular fuzzy numbers are used to express the criteria and criteria weight evaluation. The remaining of this paper is organized as follows. In section 2, the algorithm for the proposed approach namely Hamming distance method with Shannon entropy concept is explained. Section 3; validate the proposed approach by using real data in one of local university in Malaysia. The discussion on the obtained results also presented. Finally, the last sections conclude the paper.

Hamming Distance Method With Shanonn Entropy Concept:

The proposed method which is Hamming distance method with Shannon entropy concept can be used in solving any decision making problem. However, for certain circumstances, some adjustment might be made to harmonize with the proposed algorithm. As for the essential requirement, the evaluation process is done by m decision makers, $E=\{E_1,E_2,\ldots,E_m\}$ in the form of linguistic variables by using triangular fuzzy numbers. The basic steps for the proposed algorithm are presented as follows:

Step 1: Construct a decision matrix for ideal alternative.

The decision matrix for ideal alternative that represents the optimum values of *n* selection criteria $C=\{C_1,C_2,\ldots,C_n\}$ is given as follow:

$$I=[v_1,v_2,\ldots,v_n]. \tag{1}$$

Step 2: Construct a decision matrix for alternatives.

The decision matrix for a set of m possible alternatives, $A=\{A_1,A_2,\ldots,A_m\}$ where x_{ij} represent the linguistic assessment on the utility ratings of alternative $A_i\,(i=1,2,\ldots,m)$ with respect to *n* selection criteria $C=\{C_1,C_2,\ldots,C_n\}$, is given as follow:

$$D=\begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array}\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array}, \tag{2}$$

Step 3: Construct a decision matrix for weight (criteria importance).

The weighting matrix for criteria weight, w_{ij} which represents the relative importance of *n* selection criteria $C_j\,(j=1,2,\ldots,n)$ given by the decision maker, is unfolded as follow:

$$W=\begin{array}{c} \\ E_1 \\ E_2 \\ \vdots \\ E_m \end{array}\begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{m1} & w_{m2} & \cdots & w_{mn} \end{bmatrix} \end{array}. \tag{3}$$

Step 4: Construct an interval-valued fuzzy number.

The interval performance matrix for alternatives, ideal alternatives and criteria weight, are derived by using α-cut of triangular fuzzy number and shows as follows respectively:

i) The interval decision matrix for the ideal alternative:

$$I_\alpha = \left[\left[(v_1)_\alpha^l,(v_1)_\alpha^u\right],\left[(v_2)_\alpha^l,(v_2)_\alpha^u\right],\ldots,\left[(v_n)_\alpha^l,(v_n)_\alpha^u\right]\right]. \tag{4}$$

ii) The interval decision matrix for alternatives rating:

$$D_\alpha = \begin{bmatrix} \left[(x_{11})_\alpha^i,(x_{11})_\alpha^u\right] & \left[(x_{12})_\alpha^l,(x_{12})_\alpha^u\right] & \cdots & \left[(x_{1n})_\alpha^l,(x_{1n})_\alpha^u\right] \\ \left[(x_{21})_\alpha^l,(x_{21})_\alpha^u\right] & \left[(x_{22})_\alpha^l,(x_{22})_\alpha^u\right] & \cdots & \left[(x_{2n})_\alpha^l,(x_{2n})_\alpha^u\right] \\ \vdots & \vdots & \cdots & \vdots \\ \left[(x_{m1})_\alpha^l,(x_{m1})_\alpha^u\right] & \left[(x_{m2})_\alpha^l,(x_{m2})_\alpha^u\right] & \cdots & \left[(x_{mn})_\alpha^l,(x_{mn})_\alpha^u\right] \end{bmatrix}. \tag{5}$$

iii) The interval decision matrix for criteria weight:

$$W_\alpha = \begin{bmatrix} \left[(w_{11})_\alpha^L,(w_{11})_\alpha^U\right] & \left[(w_{12})_\alpha^L,(w_{12})_\alpha^U\right] & \cdots & \left[(w_{1n})_\alpha^L,(w_{1n})_\alpha^U\right] \\ \left[(w_{21})_\alpha^L,(w_{21})_\alpha^U\right] & \left[(w_{22})_\alpha^L,(w_{22})_\alpha^U\right] & \cdots & \left[(w_{2n})_\alpha^L,(w_{2n})_\alpha^U\right] \\ \vdots & \vdots & \cdots & \vdots \\ \left[(w_{m1})_\alpha^L,(w_{m1})_\alpha^U\right] & \left[(w_{m2})_\alpha^L,(w_{m2})_\alpha^U\right] & \cdots & \left[(w_{mn})_\alpha^L,(w_{mn})_\alpha^U\right] \end{bmatrix}, \tag{6}$$

where $0 \le \alpha \le 1$. The use of different α value shows the degree of confidences in the decision makers' evaluations. The higher α values shows a higher confidence level in decision makers which means, the decision makers evaluation are nearer to the possible value of a_2 for the respective triangular fuzzy numbers [7].

Step 5: Calculating of criteria weight

The criteria weight is calculated by using Shannon's entropy concept. The interval valued fuzzy number is transformed into crisp number before using Shannon's entropy concept.

Step 5.1: Calculate the crisp value of interval weight [12]:

$$w_{ij} = \frac{\left(w_{ij}^l + w_{ij}^u\right)}{2}, \tag{7}$$

Consequently, a crisp value matrix representing a relative weight of each criterion from the decision makers' evaluation is expressed as:

$$W = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1n} \\ w_{21} & w_{22} & \cdots & w_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ w_{m1} & w_{m2} & \cdots & w_{mn} \end{bmatrix}, \tag{8}$$

Step 5.2: Calculate entropy values e_j as:

$$e_j = -k\sum_{i=1}^{m} w_{ij} \ln w_{ij}, \quad j = 1,\ldots,n \tag{9}$$

where k is constant and let $k = (\ln m)^{-1}$. If $w_{ij} = 0$, then $w_{ij} \ln w_{ij}$ is equal to 0.

Step 5.3: Calculate the degree of diversification, d_j:

$$d_j = 1 - e_j, \quad j = 1,\ldots,n \tag{10}$$

Step 5. 4: Calculate the criteria weight, w_j :

$$w_j = \frac{d_j}{\sum_{k=1}^{n} d_k}. \tag{11}$$

Step 6: Calculating the distance values.

The distance values are calculated by using weighted Hamming distance method:

$$d_{WHD}(I,D) = \sum_{j=1}^{n}\left(w_j\left|v_j^l - x_{ij}^l\right| + w_j\left|v_j^u - x_{ij}^u\right|\right). \tag{12}$$

Step 7: Ranking the alternatives.

Step 8: Repeat step 4, 5, 6 and 7 for different values of α.

The use of different α values may yield different results of the ranking of the alternatives.

Step 9: Select the best alternative.

- Noted that this algorithm represented for one expert. If there is more than one expert, the average distance value between the *m* decision makers is identify and use as final result.

Performance Appraisal:

In this case, the score from the performance appraisal reports from one of institute in University Malaysia Perlis, UniMAP for the year 2010 is applied to validate the proposed approach. 21 officer assessed which is the academic officer, will be assessed based on 14 criteria. Since the evaluation marks are in the forms of crisp numbers, those marks are fuzzified into linguistic variables. These linguistic variables are represents by a set of linguistic terms captured in the forms of triangular fuzzy numbers which is build based on the discussion and preferences from two decision makers. The linguistic terms that represent the range of the performance are ranging from 'terrible' to 'excellent'. As for the linguistic variables for criteria weight, it is inspired from Wang and Lee (2009), since the decision makers find it's suitable and appropriate to be use.

Discussion:

The information and summarization of these steps are presented as follows:

Step 1: The ideal alternative vector (1) is build based on the linguistic variables presented in Table and Fig. 1. Eventually, both the decision makers had given the same and highest evaluation score for the ideal alternative which is 'Excellent' performance for all 14 criteria.

Step 2: Similar with the previous step, by using the proposed linguistic variables, the decision matrix of the alternatives against 14 criteria is build. Appendix 1 shows the evaluation score on each alternative by two decision makers.

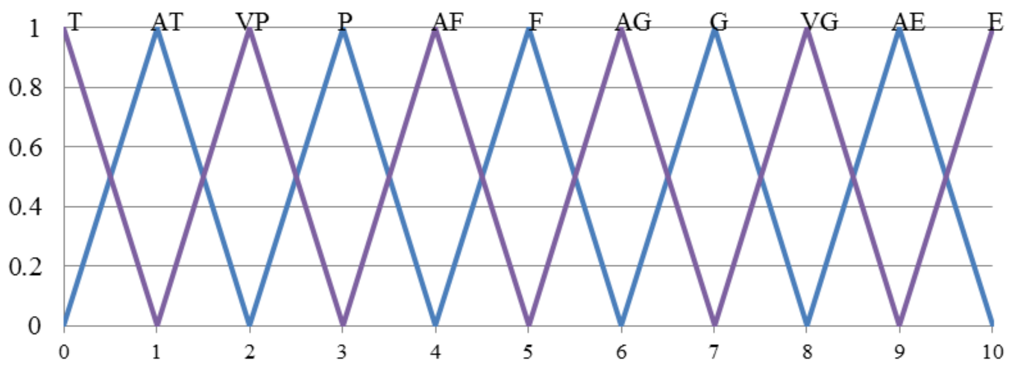

Fig. 1: The fuzzy linguistic variables for each criterion.

Table 1: Fuzzy linguistic terms and respective fuzzy numbers for each criterion.

Linguistic Terms	Fuzzy Numbers
Terrible (T)	(0, 0, 1)
Almost Terrible (AT)	(0, 1, 2)
Very poor (VP)	(1, 2, 3)
Poor (P)	(2, 3, 4)
Almost fair (AF)	(3, 4, 5)
Fair (F)	(4, 5, 6)
Almost Good (AG)	(5, 6, 7)
Good (G)	(6, 7, 8)
Very Good (VG)	(7, 8, 9)
Almost Excellent (AE)	(8, 9, 10)
Excellent (E)	(9, 10, 10)

Step 3: By using the linguistic variable as shown in Table 2 and Fig. 2, the weighting matrix (3) that represented the 14 criteria weight is build. Table 3 marked the criteria weight evaluation score by two decision makers.

Table 2: Fuzzy linguistic terms and respective fuzzy numbers for each criteria weight.

Linguistic Terms	Fuzzy Numbers
Very Low (VL)	(0, 0, 0.2)
Low (L)	(0.05, 0.2, 0.35)
Medium Low (ML)	(0.2, 0.35, 0.5)
Medium (M)	(0.35, 0.5, 0.65)
Medium High (MH)	(0.5, 0.65, 0.8)
High (H)	(0.65, 0.8, 0.95)
Very High (VH)	(0.8, 1, 1)

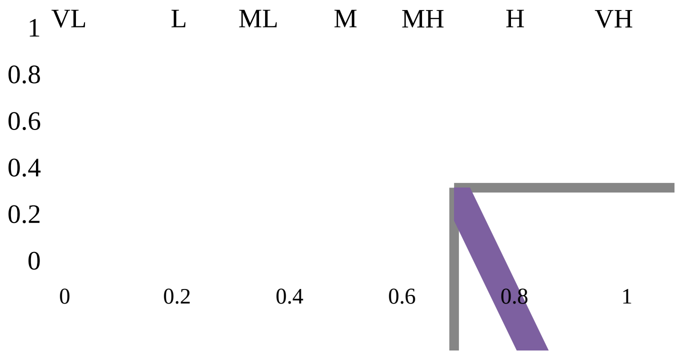

Fig. 2: The fuzzy linguistic variables for each criteria weight.

Table 3: Criteria weight evaluation for the year 2010.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
DM1	MH	H	H	H	H	VH	H	MH	MH	H	VH	VH	H	H
DM2	H	MH	VH	H	H	H	MH	MH	MH	MH	VH	H	MH	H

Step 4: The interval valued fuzzy numbers of performance matrixes for the ideal alternative (4), the alternatives (5) and criteria weights (6) are derived by using α-cut of triangular fuzzy numbers.
Step 5: To determine the criteria weight, Shannon entropy concept (7-11) will be used. The entropy based weights for each criterion at each α level are determined. Table 4 marked the criteria weight at α=0. According to the Shannon entropy concept, C11 is considered as the most important criteria followed by C3, C6 and C12.

Table 4: Result of criteria weight at α=0.

α	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
0	0.058	0.058	0.104	0.083	0.083	0.104	0.058	0.033	0.033	0.058	0.125	0.104	0.058	0.042

Step 6: The distance values for the ideal alternative and the alternatives are obtained by using weighted Hamming distance method (12).
Step 7: According to the distance values, the alternatives are rank in ascending order. The alternative with the least distance values is considered as the best alternative.
Step 8: The steps 4 to 7 are repeated by using different α values, $\alpha \in [0,1]$. Table 5 illustrated the ranking of the alternatives at α=0. Usually, for some alternatives, their rankings are changing according to α value.

Table 5: Ranking of the alternatives at α=0.

α	1	2	3	4	5	6	7	8	9	10	11
0	A3	A8	A13, A19		A4	A9	A22	A12, A17		A10, A20	

α	12	13	14	15	16	17	18	19	20	21
0	A1	A11	A5	A6	A21	A2	A14	A7	A18	A15

Step 9: Based on the ranking of the alternatives, the best performance of academic officers can be identify at the different α values. Apparently, based on Table 5, alternative A3 is likely to be considered as the best alternative.

Conclusion:

In this paper, Hamming distance method with Shannon entropy concept is proposed to select the best performance of academic officer in UniMAP, Malaysia. The use of criteria weight will help to identify which criteria are the most important criteria in solving this problem. In the proposed method, the application of fuzzy set theory is also embedded since most of the criteria assessments are done in qualitative and subjective measurement. As a result from the application of the proposed method, the ranking of the academic officers based on their overall evaluation on 14 criteria is made. The final results show that the most important criterion is belonging to C11, while the performance from academic officer, A3 is considered as the best performance. Aside from solving performance appraisal problem, the proposed method also can be used in solving any decision making problem. In upcoming research, we would like to extend this research by using the appropriate method in evaluating ideal alternative hence improving the proposed algorithm.

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Appendix 1: Decision makers 1 and 2 evaluation on alternatives performance against the criteria for the year 2010.

	DM	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
A1	D1	ME	ME	ME	VG	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	VG	ME	ME	VG	ME	ME	ME	ME	ME	ME
A2	D1	VG	VG	VG	VG	VG	ME	ME	ME	VG	VG	ME	VG	ME	VG
	D2	ME	VG	ME	VG	ME	ME	ME	ME	ME	VG	ME	ME	ME	VG
A3	D1	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	E	ME	ME	ME	ME	E	ME	ME
A4	D1	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	E	ME	ME	ME	ME	E	ME	VG	VG	ME	ME	ME	ME	ME
A5	D1	VG	ME	ME	VG	VG	ME	ME	ME	ME	ME	ME	VG	VG	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	VG
A6	D1	VG	VG	VG	VG	VG	ME	ME	ME	VG	ME	VG	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A7	D1	VG	VG	VG	VG	VG	ME	VG	VG	VG	VG	VG	ME	ME	ME
	D2	ME	ME	ME	ME	VG	ME	VG	ME	ME	ME	VG	ME	ME	ME
A8	D1	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	VG	ME	ME
	D2	E	ME	E	ME	ME	ME	ME	ME	E	E	ME	ME	ME	ME
A9	D1	VG	ME	ME	ME	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	E	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A10	D1	ME	ME	VG	VG	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A11	D1	ME	ME	ME	VG	VG	ME	ME	ME	ME	ME	ME	VG	VG	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	VG	ME
A12	D1	ME	ME	ME	ME	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	VG	ME	ME	VG	ME	ME	ME	ME	ME	ME
A13	D1	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A14	D1	VG	VG	VG	VG	VG	ME	ME	VG	ME	VG	VG	ME	ME	ME
	D2	ME	VG	ME	ME	VG	ME	ME	VG	ME	ME	VG	ME	ME	VG
A15	D1	VG	VG	VG	VG	VG	VG	VG	VG	ME	ME	VG	VG	ME	ME
	D2	VG	ME	ME	VG	ME	ME	ME	VG	ME	ME	VG	VG	ME	ME
A16	D1	ME	ME	ME	VG	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	VG	ME	ME	ME	ME	ME	ME
A17	D1	VG	VG	VG	VG	VG	ME	ME	VG	ME	VG	VG	ME	ME	ME
	D2	VG	ME	ME	VG	ME	ME	ME	ME	VG	ME	VG	VG	ME	VG

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Continue Appendix 1: Decision makers 1 and 2 evaluation on alternatives performance against the criteria for the year 2010.

	DM	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
A18	D1	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A19	D1	ME	ME	ME	VG	VG	ME	ME	ME	ME	ME	ME	VG	ME	ME
	D2	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME	ME
A20	D1	VG	VG	VG	VG	VG	ME	ME	ME	ME	VG	ME	VG	ME	VG
	D2	ME	ME	ME	ME	VG	E	ME	ME	ME	ME	ME	ME	ME	VG
A21	D1	ME	ME	ME	ME	VG	ME	ME	ME	ME	ME	ME	ME	ME	ME
	D2	ME	ME	ME	ME	ME	ME	VG	ME	ME	ME	ME	ME	ME	ME