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WEB SERVER FUTURE PLANNING DECISION ANALYSIS - FUZZY LINGUISTIC WEIGHTED APPROACH

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ABSTRACT

In this paper, fuzzy weighted approach is used to solve the multi-criteria decision making problem in a Web server system. The assessments of Web server by Web administrators are assigned using linguistic terms. The overall assessments of alternatives, with respect to every criteria, are allowed by different weights using a symmetrical triangular fuzzy number with fixed interval confidence. Web administrators' inconsistent optimistic levels can be flexibly assigned by different desired index of optimism.

Keywords: ***Fuzzy number, Multi-criteria decision making, Confidence interval***

1.0 INTRODUCTION

Web server capacity upgrading/planning frequently involves many complex components such as link capacity, redundancy of information resources, advanced load balancing approaches, etc. Web server administrator will be facing difficulties in making their decisions based on imprecise factors, for instance, fluctuating behaviour of Web traffic, evolutionary network technologies, financial limitation, etc.

In order to handle humans' subjective thoughts and judgements under complex circumstances, extensive studies have been done to overcome the problem where the traditional Saaty's analytic hierarchy process (AHP) [1] is facing a very unbalanced scale of estimation. Yiping Fan et al. [2] used the fuzzy relation in the AHP for solving the multiple vague criteria decision-making by establishing the fuzzy relation between the vague criteria and some measurable items. Chung-Hsing et al. [3] proposed an algorithm for solving general fuzzy multi-criteria decision making problem involving fuzzy data expressed by means of linguistic terms. To handle human's subjective judgements, Don-Lin Mon [4] has proposed a fuzzy AHP based on entropy weight to evaluate a weapon systems which involves multiple criteria. However, most of the mentioned methods involve complicated matrix vector calculations. Hence, an efficient multi-criteria decision method is vital to accelerate the process.

In the following literature survey, Web server performance improvement approaches can generally be categorised as caching approach [5-7], establishing redundancy of Web servers [8-10], and intelligent Web traffic handling methods [11-18].

In this paper, Web server administrators will judge the alternatives, such as caching feature, intelligent workload handling methods as well as redundant servers to evaluate, and select the alternatives priority for upgrading their system. Generally, the subjective judgements given by the administrators are vague and imprecise due to the inconsistent administrators' experiences, lack of experimental data and miscellaneous system conditions. The implementation of fuzzy set theory to handle the multi-criterion problem is suitable to capture the subjectiveness and vagueness decisions. Fuzzy linguistic term with symmetrical triangular fuzzy number will be utilised to indicate the influence strength of the judgements in the hierarchy elements. Linguistic term approach is convenient for decision-makers to express their assessment. Furthermore, each of the criteria is assigned with different weights to exhibit the influence strength to the respective alternative. This is done to ensure the flexibility of judgements.

The approaches of interval arithmetic, confidence level fuzzy sets (α- cut) and the index of the decision-maker optimism level (l), are employed to determine the desired alternative. α-level fuzzy sets are utilised to avoid the complexity and controversial fuzzy ranking to ensure the predefined fuzzy number can confidently rank[19]. Different optimism index (l) will be used depending on the decision-maker's optimism level. To examine the consistency of the fuzzy ranking, preceding of a is chosen to exhibit the reliability of the precedence alternative.

2.0 HIERARCHY STRUCTURE MODEL

Based on Analytic Hierarchy Process [1], a structure model is developed. A hierarchy structure is established with three alternatives (A_1, A_2, A_3) and three criteria (C_a, C_b ,C_b) to select the greatest finite alternatives in favour of improving the Web server performance. The hierarchy structure is described in Fig. 1.

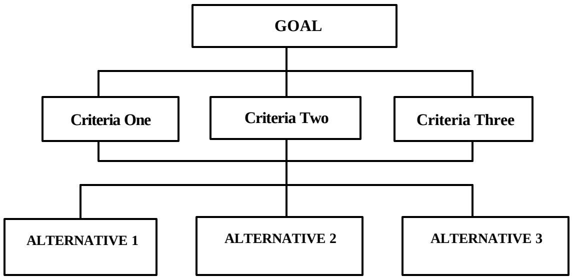

Fig. 1: Hierarchy structure model

3.0 SUBJECTIVE JUDGEMENT EVALUATION - LINGUISTIC TERM APPROACH

3.1 Fuzzy Number

Fuzzy number with symmetrical triangular membership function is utilised to evaluate the influence strength of the alternatives in the hierarchy structure. A triangular membership function is confined by three parameters {*x*, *y*, *z*} as follows:

$$Triangle(a : x, y, z) = \begin{cases} 0, & a \le x \\ \dfrac{a-x}{y-x}, & x \le a \le y \\ \dfrac{z-a}{z-y}, & y \le a \le z \\ 0, & z \le a \end{cases}$$

A level threshold ($0<a<1$) of the fuzzy set is defined to show the decision-makers' confidence to their judgements. The definition of the symmetrical triangular fuzzy number with the interval confidence at level a can be determine as:

$$M_a = [x_a, z_a] = [(y-x)\,a + x, (y-z)\,a + z] \qquad \forall \quad a \in [0,1]$$

Table 1: Triangular Fuzzy Number

Triangular Parameters			Triangular Fuzzy number with a-level	
X	y	Z	(y-x) a + x	(y-z) a + z
1	1	3	1	$-2a + 3$
1	3	5	$2a + 1$	$-2a + 5$
3	5	7	$2a + 3$	$-2a + 7$
5	7	9	$2a + 5$	$-2a + 9$
7	9	11	$2a + 7$	$-2a + 11$
9	11	11	$2a + 9$	11

For positive fuzzy numbers with the interval of confidence at level a, M_g and N_g the basic operations [19] are:

$M_a = [m^-_a, m^+_a]$, $N_a = [n^-_a, n^+_a]$ $\quad \forall\, \gamma \in [0, 1]$
and $\forall\, m^-_a, n^-_a, m^+_a, n^+_a \in \Re$

$$M_a \oplus N_a = [\, m^-_a + n^-_a,\ m^+_a + n^+_a \,]$$
$$M_a\, \theta\, N_a = [\, m^-_a - n^-_a,\ m^+_a - n^+_a \,]$$
$$M_a \otimes N_a = [\, m^-_a \times n^-_a,\ m^+_a \times n^+_a \,]$$
$$M_a \varnothing N_a = [\, m^-_a / n^-_a,\ m^+_a / n^+_a \,]$$

3.2 Linguistic Judgement Determination

The alternative(A_i) respect to the C_a(Criteria A) linguistic term set is assigned as:

{ *Extremely Expensive(EEx), Expensive(Ex), Above Average(AA), Average(A), Economic(Ec), Very Economic(VEc)*}

Similarly, the alternative(A_i) respect to the C_b(Criteria B) and C_c (Criteria C) linguistic term set are defined as:

{ *Very Poor(VP), Poor(P), Average(A), Above Average(AA), Good(G), Extremely Good(EG)* }

For the weighting scores, the evaluation of the strength influence is represented by the linguistic term set as below:

{ *Very Weak(VW), Weak(W), Average(A), Above Average (AF), Strong(S), Extremely Strong(ES)* }

The predefined linguistic term sets and their respected fuzzy numbers are illustrated as follows:

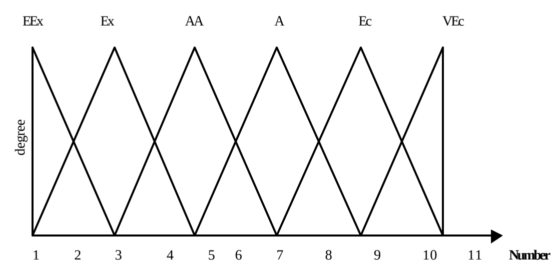

Fig. 2: Linguistic Terms C_a in Fuzzy Judgement

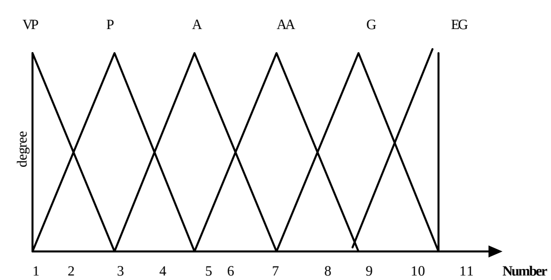

Fig. 3: Linguistic Terms C_b and C_c in Fuzzy Judgement

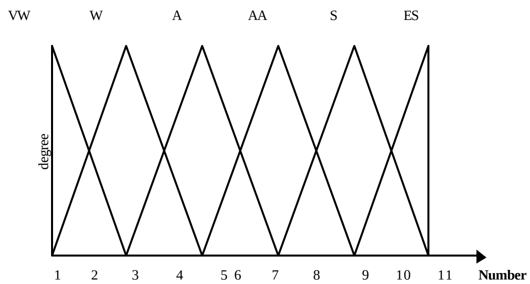

Fig. 4: Linguistic Terms Evaluation Weighted Strength

4.0 ALGORITHM AND METHODOLOGY

Fuzzy logic concepts are used to solve the multi-criteria decision making problem. The linguistic influence strength is assigned according to (3.2). The greater the value of decision-makers' assessments, the more relevant and suitable the alternative to its respected criteria items. The procedures of this methodology is shown as follows:

Step 1

Compare among the alternatives' influence strength with respect to its criteria items using fuzzy linguistic performance scores (3.2). Example: the fuzzy linguistic scores based on the triangle fuzzy numbers are: {*Extremely Expensive(EEx), Expensive(Ex), Above Average(AA), Average(A), Economic(Ec), Very Economic(VEc)*}.

Step 2

Table 2: Linguistic fuzzy scores for alternatives with respect to the criteria items

Criteria a	Weights	A1	A2	A3
(i)	LW_1	FL_{a1}	FL_{a2}	FL_{a3}
(ii)	LW_2	FL_{b1}	FL_{b2}	FL_{b3}
(iii)	LW_3	FL_{c1}	FL_{c2}	FL_{c3}

In Table 2, the weights of criteria items and the fuzzy scores of the alternatives are assigned as LW_1, FL_{a1}, FL_{a2}, FL_{a3}….[20]. Based on the associated fuzzy number, convert the linguistic term to fuzzy number.

Step 3

The final fuzzy scores of Alternative 1 is represented by $F(A_1)$. The $F(A_1)$ evaluation involves fuzzy number multiplication and addition using interval arithmetic and ∝-cuts based on Table 1. Let the ∝-cuts of $F(A_1)$, $F(A_2)$ and $F(A_3)$ represented as $[A1_1^{(\propto)}, A1_2^{(\propto)}]$, $[A2_1^{(\propto)}, A2_2^{(\propto)}]$ and $[A3_1^{(\propto)}, A3_2^{(\propto)}]$ respectively, where $\propto \in [0,1]$. The $F(A_1)$ can be evaluated as follows:

$$F(A_1) = LW_1 \otimes FL_{a1} \oplus LW_2 \otimes FL_{b1} \oplus LW_3 \otimes FL_{c1}$$

Similarly $F(A_2)$ and $F(A_3)$ are defined as below:

$$F(A_2) = LW_1 \otimes FL_{a2} \oplus LW_2 \otimes FL_{b2} \oplus LW_3 \otimes FL_{c2}$$

$$F(A_3) = LW_1 \otimes FL_{a3} \oplus LW_2 \otimes FL_{b3} \oplus LW_3 \otimes FL_{c3}$$

where $F(A_1)$, $F(A_2)$ and $F(A_3)$ are symmetrical triangular fuzzy number.

Step 4

To involve the index of decision-makers' optimism level(λ where $\lambda \in [0,1]$) with fixed ∝, let us denote $DM_\propto^\lambda(A1)$, $DM_\propto^\lambda(A2)$ and $DM_\propto^\lambda(A3)$ as the scores with fixed ∝ and fixed λ:

$$DM_\propto^\lambda(A1) = \lambda A1_l^{(\propto)} + (1-\lambda)\, A1_r^{(\propto)}$$
$$DM_\propto^\lambda(A2) = \lambda A2_l^{(\propto)} + (1-\lambda)\, A2_r^{(\propto)}$$
$$DM_\propto^\lambda(A3) = \lambda A3_l^{(\propto)} + (1-\lambda)\, A3_r^{(\propto)}$$

Step 5

Normalise the $DM_\propto^\lambda$ value to evaluate the highest degree of suitability among the selection with respect to A1, A2 and A3 for fixed ∝ and fixed λ. The normalised values are denoted as $No_\propto^\lambda(A1)$, $No_\propto^\lambda(A2)$ and $No_\propto^\lambda(A3)$. Let

$$No_a^l(A_1) = \frac{DM_a^l(A_1)}{DM_a^l(A_1) + DM_a^l(A_2) + DM_a^l(A_3)}$$

$$No_a^l(A_2) = \frac{DM_a^l(A_2)}{DM_a^l(A_1) + DM_a^l(A_2) + DM_a^l(A_3)}$$

$$No_a^l(A_3) = \frac{DM_a^l(A_3)}{DM_a^l(A_1) + DM_a^l(A_2) + DM_a^l(A_3)}$$

where $\lambda \in [0,1]$, $\propto \in [0,1]$, $N_\propto^\lambda(A1) \in [0,1]$, $N_\propto^\lambda(A2) \in [0,1]$ and $N_\propto^\lambda(A3) \in [0,1]$.

5.0 NUMERICAL EVALUATION

Consider a public accessible Web server on the Internet. The Web server system consists of two redundant servers to handle the large population of unknown users' accesses. The Web server is connected to a switch and a router that is connected to the ISP then to the Internet. The backbone is connected to the Internet through a T1 link. Due to high user demands, the Web site exhibits extremely slow response and traffic congestion. In order to overcome Web traffic congestion, Web server administrators have to monitor the performance of the Web server and discover several factors that enormously influence the Web server overall performance.

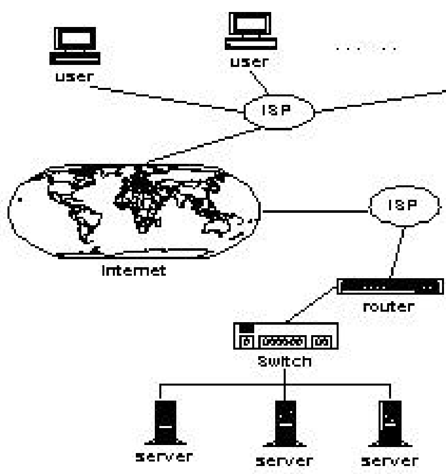

Fig. 5: Web server system and Internet connectivity

Assume that the three alternatives upgrade features are caching(A_1), intelligent load balancing approaches(A_2) and redundant server(A_3). However, the priority of the select ion within the three alternatives is governed by the economy(C_a) and bursty traffic adaptation(C_b) and their special advancement(C_c). To solve the multiple criteria decision making problem, fuzzy approach is utilised to capture the vagueness of the descriptions and judgements among the Web server administrators. The subjective evaluations of the alternatives is based on the follow descriptions:

Table 3: Fuzzy linguistic scores of three alternative

Criteria	Weight	A1	A2	A3
Criteria A(Economy)				
a. Software cost	W	A	AA	A
b. Hardware cost	S	Ex	AA	VEx
c. Support cost	A	Ex	AA	Ex
Criteria B (Bursty traffic adaptation)				
a. Latency decrease	AA	G	G	AA
b. Error rate decrease	A	A	G	A
c. Bandwidth utilisation	S	G	AA	G
Criteria C (Advancement)				
a. Security feature	W	G	A	P
b. Redundancy (backup)	W	A	A	G
c. Scalability	A	P	AA	AA

Initially, assume the value of $\propto$ is equivalent to 0.05 and the decision-maker with the index of optimism, λ =0.05. Based on Table 4 and the equation (4-8), the final fuzzy scores can be obtained as follows:

$$F(A_1) = LW_1 \otimes FL_{a1} \oplus LW_2 \otimes FL_{b1} \oplus LW_3 \otimes FL_{c1}$$
$$= \tilde{1} \otimes \tilde{7} \oplus \tilde{7} \otimes \tilde{3} \oplus \tilde{3} \otimes \tilde{3} \oplus \tilde{5} \otimes \tilde{9} \oplus \tilde{3} \otimes \tilde{5} \oplus \tilde{7} \otimes \tilde{9} \oplus \tilde{1} \otimes \tilde{9} \oplus \tilde{3} \otimes \tilde{5} \oplus \tilde{3} \otimes \tilde{1}$$
$$= 140.33$$

$F(A_2) = 158.18$ $\quad$ $F(A_3) = 138.38$

The normalised value for $No_{\propto}^{\lambda}(A1)$, $No_{\propto}^{\lambda}(A2)$ and $No_{\propto}^{\lambda}(A3)$ are obtained as follows:

$$No_{\propto}^{\lambda}(A1) = 0.321,$$
$$No_{\propto}^{\lambda}(A2) = 0.362,$$
$$No_{\propto}^{\lambda}(A3) = 0.317$$

The priority of the upgrading alternatives are in the order of intelligent load balancing approaches (A_2), caching(A_1) and redundant server(A_3). Regardless of the variety of a values, the results are consistent with the priority of A_2, A_1 and following by A_3. The consistency of the result assures the acceptability and correctness of the selected alternative. To examine the consistency and reliability of the fuzzy ranking, preceding value of a is chosen with three different level of optimism such as l =0.05, l =0.5 and l =0.95 depending on the optimism level of the Web administrator. The results are illustrated in Fig. 6, 7 and 8, where different levels of Web administrators' optimism have no influence in the consistency of the alternatives priority.

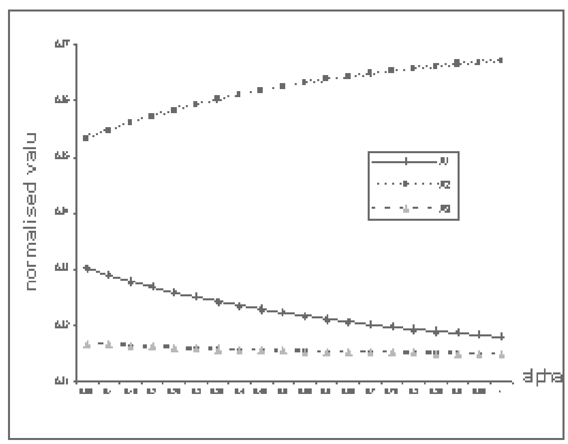

Fig. 6: Normalised value of $No_{\propto}^{\lambda}(A_1)$, $No_{\propto}^{\lambda}(A_2)$ and $No_{\propto}^{\lambda}(A_3)$ for optimistic decision-maker

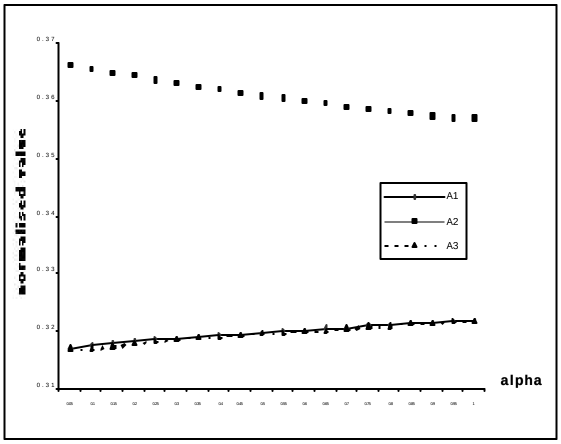

Fig. 7: Normalised value of $No_{\propto}^{\lambda}(A_1)$, $No_{\propto}^{\lambda}(A_2)$ and $No_{\propto}^{\lambda}(A_3)$ for moderate decision-maker

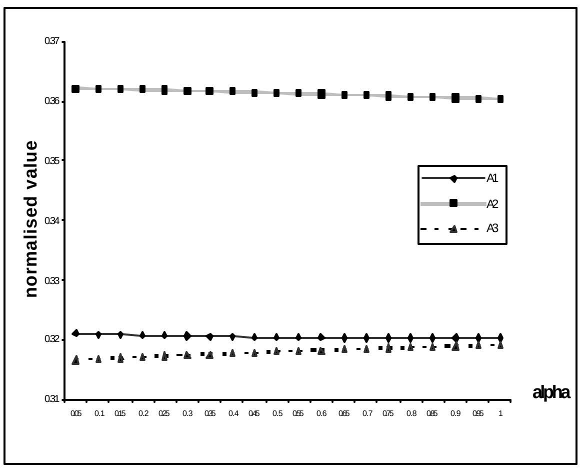

Fig. 8: Normalised value of $No_{\propto}^{\lambda}(A_1)$, $No_{\propto}^{\lambda}(A_2)$ and $No_{\propto}^{\lambda}(A_3)$ for pessimistic decision-maker

5.1 Comparison With AHP Method

The Saaty's AHP approach is based on the pairwise comparison among the alternatives with its associated criteria. The prioritisation of the alternatives can be obtained by determining the eigenvector of the pairwise matrix that is developed by the alternatives. The previous numerical example is evaluated by this nonfuzzy method. The interval value is represented by the mean and the ranking of the alternatives is obtained as follows:

The pairwise comparison assessments matrices (Table 3):

$$\left.\begin{array}{ll} \text{Criteria-A} = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 4 \\ 1/2 & 1/4 & 1 \end{bmatrix} & \text{Criteria-B} = \begin{bmatrix} 1 & 1/2 & 2 \\ 2 & 1 & 4 \\ 1/2 & 1/4 & 1 \end{bmatrix} \\ \text{Criteria-C} = \begin{bmatrix} 1 & 1/2 & 1/2 \\ 2 & 1 & 1 \\ 2 & 1 & 1 \end{bmatrix} & \text{Criteria Comparison} = \begin{bmatrix} 1 & 1/4 & 4 \\ 4 & 1 & 8 \\ 1/4 & 1/8 & 1 \end{bmatrix} \end{array}\right\} \text{(a)}$$

The row sum is calculated and normalises each of the pairwise matrices. Below is the eigenvector for each alternatives with respect to each criteria and the weighted eigenvector (multiply the normalised matrix with the eigenvector of the criteria):

$$M_{overall} = \begin{bmatrix} 0.286 & 0.286 & 0.200 \\ 0.571 & 0.571 & 0.400 \\ 0.143 & 0.143 & 0.400 \end{bmatrix} * \begin{bmatrix} 0.221 \\ 0.711 \\ 0.068 \end{bmatrix} = \begin{bmatrix} 0.2802 \\ 0.5594 \\ 0.1605 \end{bmatrix}$$

The results concluded that the ranking of the alternatives are A_2, A_1 and A_3. The unbalanced of the AHP scoring shows the half of the nondiagonal elements (a) with the range of 1 to 8, while others with the range of 1/8 to 1/2. The gap of the integer value is between 8 and 3/8 respectively. This will cause a very uneven outcome if irrelevant judgement has been assessed. Furthermore, this method is not capable to capture the vagueness of the mapping of one's scoring to a real value instead of fuzzy scoring. Finally, the different optimistic levels of DMs cannot be flexible modelled according to different behaviours of the DMs.

6.0 CONCLUSION

In this paper, fuzzy linguistic term of Web administrators' assessments are used to capture the fuzziness and subjectiveness of prioritising the upgrading alternatives selection in a multi-criteria decision making problem in a Web server system. The traditional methods such as AHP or synthetic evaluation method are not able to capture the fuzziness of the decision-makers assessments. Further, the proposed method with the predefined fuzzy number and certain confidence of level (*a-cut-method*) is capable of avoiding the conflict and unreliability of fuzzy ranking problem. The fuzzy approach has demonstrated the consistency of confidence in decision-making since the different levels of optimism and *a*-levels have no influence to the evaluation outcome. The upgrading alternatives as well as its associate criteria may involve more candidates under different circumstances and specific conditions. The proposed method aims to provide alternatives for Web administrators when selecting proper optimal solution to prioritise the existing multi-criteria decision making problem.

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