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Hierarchical Concept Applied with Fuzzy Theory

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***Abstract**- The Analytic Hierarchy Process (AHP) is a Multi Criteria Decision Making technique that represents a complex decision problem as a hierarchy with different levels to evaluate software quality. Each level contains different elements with a relevant common characteristic. Using AHP, a cardinal measure of the importance or priority of each element in a level is obtained by pair-wise comparisons of all elements in that level. Each element in level serves as the basis for effecting pair-wise comparisons of the elements in the immediate lower level of the hierarchy.AHP gives many imprecise and uncertain results in many complex situations. Therefore, fuzzy theory is amalgamate with AHP to give more better results for evaluating quality of a software.*

***Keywords**- Quality, AHP, Fuzzy theory, multi criteria decision making, FAHP.*

I. INTRODUCTION

The Analytic Hierarchy Process (AHP) has been developed by T. Saaty (1977, 1980, 1988, 1995) and is one of the best known and most widely used MCA approaches. It allows users to assess the relative weight of multiple criteria or multiple options against given criteria in an intuitive manner. In case quantitative ratings are not available, policy makers or assessors can still recognize whether one criterion is more important than another. Therefore, pairwise comparisons are appealing to users. Saaty established a consistent way of converting such pairwise comparisons (X is more important than Y) into a set of numbers representing the relative priority of each of the criteria. The general methodology of AHP is described in detail in Saaty[1] and Zahedi [2] have made detailed reviews of its various applications. To determine the degree of quality requirements achieved in the software, the assessment of software architecture for quality is to be conducted at various phases of the software development life cycle (SDLC)[3][4]. So Software architecture is described as various collections of architectural decisions that satisfy stake holder's choice of having multiple quality requirements [5].Applying AHP in a standard manner can provide overall priority weights of design alternatives. All priority weights of design alternatives can be computed using the AHP standard technique. This technique takes into consideration all quality attributes, priority weights of design alternatives for individual quality attributes and priority weights among the quality attributes themselves [6**].** This technique of AHP is for more precision in selecting the design alternative. These issues can lead to an architecture better prepared for future change.

The fuzzy analytic hierarchy process (FAHP)-based decision-making method is effective for constructing an evaluation method, which can assist software developers, users and procurers in evaluating software quality to identify the most appropriate qualities, or factors in software system development. Additionally, the proposed method can help software researchers and consumers access software quality, making it highly applicable for academic and commercial purposes.

II. RELATED WORK

There are many fuzzy AHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis.

Saaty et al.[7] proposed initially the AHP process in the 1980s , he uses the pair-wise matrix to evaluate ambiguity in multi-criteria decision making problems. It is a systematic decision making method which includes both qualitative and quantitative techniques. It is being widely used in many fields for a long time. But one of the critical steps of AHP method is to set up the comparison matrixes.

Kevin K.F. Yuen et al.[8] proposed fuzzy Analytic Hierarchy Process model for evaluating the software quality of vendors. He said that the proposed model can help the developers and testers to evaluate the vendors' software applications and select the best alternative under uncertain environment.

Arun Sharma et al.[9] defined Estimation of Quality for Software Components. They presents a survey of various quality models proposed so far for non-component and component based systems. ISO 9126 is found to be more promising model among all. A weight assignment technique is used by using the Analytical Hierarchical Process (AHP) concept.

Changli Sun et al.[10] describe Software Documents Quality Measurement- A Fuzzy Approach in which they presents a method of measuring the quality of software document, and applied this method. Through measurement quality of summary design, they can see the method is indeed feasible.

Avadhesh Kumar et al.[11] described a new aspect-oriented software quality model AOSQUAMO is proposed. This model is an extension of ISO/IEC 9126 software quality standards.In order to evaluate quality of proposed model as a single parameter, Analytic Hierarchy Process (AHP) is applied. Pair-wise relative weights of characteristics and sub-characteristics have been taken through a survey on 12 experts of the field and mean of the collected samples have been considered as pair-wise relative weights.

X.Cai, M.R. Lyu et al.defined[12] Component Based Soft-ware Engineering: Technologies, Development Frameworks, and Quality Assurance Schemes.

III. AHP PROCESS

The basic procedure to carry out the AHP for analyzing quality of software consists of the following steps:

1. Structuring a decision problem and selection of criteria:

The first step is to decompose a decision problem into its constituent parts. In its simplest form, this structure comprises a goal or focus at the topmost level, criteria at the intermediate levels, while the lowest level contains the options. Arranging all the components in a hierarchy provides an overall view of the complex relationships and helps the decision maker to assess whether the elements in each level are of the same magnitude so that they can be compared accurately or exactly. An element in a given level does not have to function as a criterion for all the elements in the level below. Each level may represent a different cut at the problem so the hierarchy does not need to be complete (Saaty , 1990).

When constructing hierarchies it is very essential to consider the environment surrounding the problem and to identify the issues or attributes that contribute to the solution as well as to identify all participants associated with the problem.

2. Priority setting of the criteria by pairwise comparison (weighing) of factors and sub factors of quality:

For each pair of criteria, the decision maker is required to respond to a question such as "How important is criterion A relative to criterion B?" Rating the relative "priority" of the criteria is done by assigning a weight between 1 (equal importance) and 9 (extreme importance) to the more important criterion, whereas the reciprocal of this value is assigned to the other criterion in the pair. The weights are then normalized and averaged in order to obtain an average weight for each criterion.

3. Pairwise comparison of options on each criterion (scoring)that is comparison of alternatives:

For each pairing within each criterion the better option is awarded a score, again, on a scale between 1 (equally good) and 9 (absolutely better), whilst the other option in the pairing is assigned a rating equal to the reciprocal of this value. Each score records how well option "x" meets criterion "Y". Afterwards, the ratings are then normalized and averaged. Comparisons of elements in pairs require that they are homogeneous or close with respect to the common attribute; otherwise significant errors may be introduced into the process of measurement (Saaty, 1990).

4. Obtaining an overall relative score for each option

In a final step the option scores are combined with the criterion weights to produce an overall score for each option. The extent to which the options satisfy the criteria is weighed according to the relative importance of the criteria. This is done by only simple weighted summation .

Finally, after judgements have been made on the impact of all the elements and priorities have been computed for the hierarchy as a whole, sometimes and with care, the less important elements can be dropped from further consideration because of their relatively small impact on the overall objective. The priorities can then be recomputed throughout, either with or without changing the judgements (Saaty, 1990).

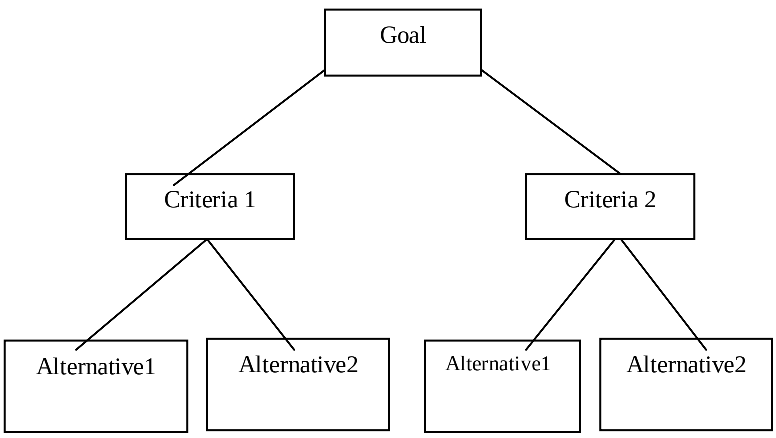


Fig 1: AHP Hierarchy

A. *Strengths and weaknesses*

1) *Strengths*

1)The advantages of AHP over other multi criteria methods are its flexibility, intuitive appeal to the decision makers and its ability to check inconsistencies (Ramanathan 2001). Generally, users find the pairwise comparison form of data input straightforward and convenient.
2)Additionally, the AHP method has the distinct advantage that it decomposes a decision problem into its constituent parts and builds hierarchies of criteria. Here, the importance of each element (criterion) becomes clear.
3)AHP helps to capture both subjective and objective evaluation measures. While providing a useful mechanism for checking the consistency of the evaluation measures and alternatives, AHP reduces bias in decision making.
4)The AHP method supports group decision–making through consensus by calculating the geometric mean of the individual pairwise comparisons (Zahir 1999).
5)AHP is uniquely positioned to help model situations of uncertainty and risk since it is capable of deriving scales where measures ordinarily do not exist (Millet & Wedley 2002).

2) Weaknesses

Despite the popularity of the AHP, many authors have expressed concern over certain issues in the AHP methodology.
1)Many researchers have long observed some cases in which ranking irregularities can occur when the AHP or some of its variants are used. This rank reversal is likely to occur e.g. when a copy or a near copy of an existing option is added to the set of alternatives that are being evaluated.
2)The AHP method can be considered as a complete aggregation method of the additive type. The problem with such aggregation is that compensation between good scores on some criteria and bad scores on other criteria can occur. Detailed, and often important, information can be lost by such aggregation.
3)With AHP the decision problem is decomposed into a number of subsystems, within which and between which a substantial number of pairwise comparisons need to be completed. This approach has the disadvantage that the number of pairwise comparisons to be made, may become very large (n(n−1)/2), and thus become a lengthy task.
4)Another important disadvantage of the AHP method is the artificial limitation of the use of the 9–point scale.

IV. FUZZY SET THEORY

In order to deal with vagueness of human thought, Zadeh[13] first introduced the fuzzy set theory. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for commonsense reasoning in decision-making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution [14]. Fuzzy sets theory providing a more widely frame than classic sets theory, has been contributing to capability of reflecting real world [15]. Modeling using fuzzy sets has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise [16].

A. Fuzzy number

Triangular fuzzy numbers can be defined as a triplet
(l, m, u). The parameters l, m, and u. respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. A triangular fuzzy number M is shown in Fig. 2 [17].
There are various operations on triangular fuzzy numbers.
Consider two TFNs $a1= (l1, m1, u1)$ and $a2 = (l2, m2, u2)$. Some of the operational axioms are as follows:

Addition:

a1 + a2 = (l1,m1,u1) + (l2,m2,u2)
= (l1+l2, m1+m2, u1+u2)

Subtraction:

a1 - a2 = (l1,m1,u1) - (l2,m2,u2)
= (l1-l2, m1-m2, u1-u2)

Multiplication:

a1 * a2 = (l1,m1,u1) * (l2,m2,u2)
= (l1*l2, m1*m2, u1*u2)

Division:

a1 / a2 = (l1,m1,u1) / (l2,m2,u2)
= (l1/l2, m1/m2, u1/u2)

B. Fuzzy Analytic Hierarchy Process

The FAHP process comprises of four major steps as discussed below:

1) Establish model and problem

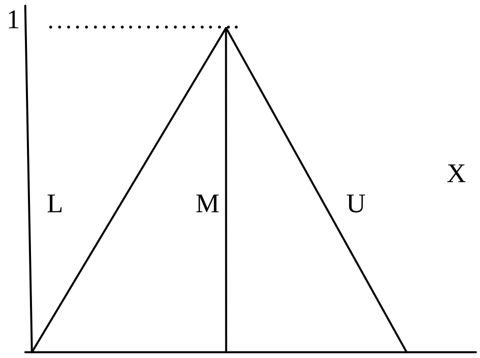
The problem should be stated clearly and decomposed into a rational system like a hierarchy. The structure can be determined by the opinion of decision makers through brainstorming or other appropriate methods.

2) Establishing triangular fuzzy numbers

In the Saaty (1980) model[18], the geometric mean represents the expert consensus and is the most widely used in practical applications. Here, the geometric mean models the triangular fuzzy numbers. Zadeh (1965) introduced the fuzzy set theory to deal with the uncertainty due to imprecision and vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. Mathematical operations and programming may also apply to a fuzzy domain.

A fuzzy set is a class of objects with a graded continuum of membership. Such a set is characterized by a membership function, which assigns to each object a membership grade between zero and one.

Figure 2 depicts a triangular fuzzy number. Since each number in the pair-wise comparison matrix represents the subjective opinion of decision makers and is an ambiguous concept, fuzzy numbers work best to consolidate fragmented expert opinions.



(1)

Fig 2: Triangular fuzzy numbers

A TFN is denoted simply as (L, M, U). As formulas (2)–(5) demonstrate, the parameters L, M and U denote the smallest possible value, the most promising value and the largest possible value, respectively, that describes a fuzzy event. The triangular fuzzy numbers u_{ij} are established as follows:

$$\tilde{u}_{ij} = (L_{ij}, M_{ij}, U_{ij}) \qquad (2)$$

$L_{ij} \leq M_{ij} \leq U_{ij}$ and L_{ij}, M_{ij}, U_{ij} ε [1/9, 9]

$$L_{ij} = \max(B_{ijk}) \qquad (3)$$

$$M_{ij} = \sqrt[n]{\pi b}_{ijk} \qquad (4)$$

$$U_{ij} = \max(B_{ij}) \qquad (5)$$

Where B_{ijk} represents a judgment of expert k for the relative importance of two criteria $C_i - C_j$.

3) Establishing fuzzy pair-wise comparison matrix and defuzzification

A= [a$_{ij}$]=

$$\begin{array}{c} \\ C1 \\ C2 \\ \\ \\ Cn \end{array} \begin{pmatrix} C1 & C2\,. & & Cn \\ 1 & a_{12} & \dots & a_{12} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ . & . & & . \\ . & . & & . \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{pmatrix} \qquad (6)$$

where $\sim a_{12}$ denotes a triangular fuzzy number for the relative importance of two criteria C1 and C2. Additionally $[a_{ij}]$ represents the triangular fuzzy numbers by the formulae (2)–(5). Various defuzzication methods are available, and the method adopted herein was derived from Liou and Wang (1992). As shown in formulae (7) and (8), this method can clearly express fuzzy perception.

$$g_{\alpha,\beta}(a_{ij}) = [\ \beta.\ f_\alpha(L_{ij}) + (1-\beta).\ f_\alpha(U_{ij})\ ],\quad 0 \le \beta \le 1,\ 0 \le \alpha \le 1 \qquad (7)$$

where $f_\alpha(L_{ij}) = (M_{ij} - L_{ij}).\ \alpha + L_{ij}$ represents the left-end value of α-cut for a_{ij} and $f_\alpha(U_{ij}) = U_{ij} - (U_{ij} - M_{ij}).\alpha$ represents the right-end value of α-cut for $a_{ij.}$

$$g_{\alpha,\beta}(a_{ij}) = 1/\ g_{\alpha,\beta}(a_{ij}),\quad 0 \le \beta \le 1,\ 0 \le \alpha \le 1,\ i>j \qquad (8)$$

Because this method can explicitly display the preferences (alpha) and risk tolerance (beta) of decision makers, decision makers can more thoroughly understand the risks they face in different circumstances. Notably, a can be viewed as a stable or fluctuating condition. The range of uncertainty is greatest when a = 0. Meanwhile, the decision making[19] environment stabilizes as a increases; simultaneously, the variance in decision making decreases. Additionally, a can be any number between 0 and 1, and analysis is normally set as the following 10 numbers, 0.1, 0.2,...,1 for uncertainty emulation. Further, a = 0 represents the upper-bound U_{ij} and lower-bound L_{ij} of TFN, and a = 1 represents the geometric mean M_{ij} in triangular fuzzy numbers. Thus, b can be viewed as the degree of pessimism in a decision maker. When b = 0, the decision maker is more optimistic, and the expert consensus is thus upper-bound U_{ij} of the TFN. When b = 1, the decision maker is pessimistic, and the number ranges from 0 to 1. However, the five numbers 0.1, 0.3, 0.5, 0.7, and 0.9 are used to emulate the state of mind of decision makers. The single pair-wise comparison matrix is expressed in formula (9).

$$g_{\alpha,\beta}(\tilde{A}) = g_{\alpha,\beta}([\tilde{a}_{ij}]) = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} 1 & g_{\alpha,\beta}(\tilde{a}_{12}) & \cdots & g_{\alpha,\beta}(\tilde{a}_{1n}) \\ 1/g_{\alpha,\beta}(\tilde{a}_{12}) & 1 & \cdots & g_{\alpha,\beta}(\tilde{a}_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ 1/g_{\alpha,\beta}(\tilde{a}_{1n}) & 1/g_{\alpha,\beta}(\tilde{a}_{2n}) & \cdots & 1 \end{bmatrix} \qquad (9)$$

4) Determine eigenvectors

Notably, λ_{max} is defined as the eigenvalue of the single pair-wise comparison matrix $g_{\alpha,\beta}(A)$.

$$g_{\alpha,\beta}(A).W = \lambda_{max} W$$

And

$$[g_{\alpha,\beta}(A) - \lambda_{max} I]\ W = 0, \qquad (10)$$

Where W denotes the eigenvector of $g_{\alpha,\beta}(A)$,

$$0 \le \beta \le 1,\ 0 \le \alpha \le 1 \qquad (11)$$

Comparing formulas (1) and (9) reveals that the traditional AHP only uses a specific figure (geometric mean) to represent expert opinions in the pair-wise comparison matrix. However, the triangular fuzzy numbers represent fuzzy opinions and expert consensus. Meanwhile, both approaches use the eigenvector method to calculate weights.

5) Consistency test

Saaty (1980) proposed a consistency index (C.I.) and consistency ratio (C.R.) to verify the consistency of the comparison matrix. The C.I. and R.I. are defined as follows:

$$C.I = \lambda_{max} - \frac{n}{n-1} \qquad (12)$$

$$C.R = \frac{C.I}{R.I} \qquad (13)$$

where R.I. represents the average consistency index over numerous random entries of the same order reciprocal matrices. If C.R ≤ 0.1, the estimate is accepted; otherwise, a new comparison matrix is solicited until C.R ≤ 0.1

V. CONCLUSION

This study proposes a fuzzy AHP algorithm for software quality evaluation and software vendor selection under uncertainty. The model uses triangular fuzzy numbers that is fuzzy theory concept Over different criterias and alternatives for evaluating software quality. For the limitation, this research considers only the problem of multiple vendor selection and it cannot deal with the quality measurement of a single project. Another limitation is the computational efficiency and complexity of the prioritization method, which will be discussed and improved in the future research.

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REFERENCES

[1] Saaty, T. L. (1980). The analytic hierarchy process. New York: McGraw Hill.

[2] Zahedi, Fatemah, 1986, ‘‘The Analytic Hierarchy Process: A Survey of the method and its applications’’, Interfaces, Vol. 16, pp.96-108.

[3] Perry D. E and A. L Wolf. ‘‘Foundations for the study of software architecture’’. ACM SIGSOFT Software Engineering Notes, 17(4), Oct. 1992, pp.40-52

[4] Bosch, J. 2004., ‘‘Software Architecture: The next step’’, In Proceedings of the First European Workshop on Software architecture (EWSA), pp. 194-199.

[5] ZHU et al. ‘‘Tradeoff and Sensitivity Analysis in Software Architecture Evaluation Using Analytic Hierarchy Process’’, 2005.

[6] Greenberg, Robert R, and Thomas R Nunamaker, 1994. ‘‘Integrating Analytic Hierarchy Process (AHP) into the multi objective budgeting models of public sector organizations’’. Socio-Economic Planning Sciences, Vol.28 No.3, pp.197-206.

[7] Saaty, T.L, “The Analytic Hierarchy Process”, McGraw Hill International, 1980.

[8] Kevin K.F. Yuen*, Henry C.W. Lau, “Evaluating Software Quality of Vendors using Fuzzy Analytic Hierarchy Process “,Vol I IMECS 2008, 19-21 March, 2008, Hong Kong.

[9] Arun Sharma, Rajesh Kumar, and P. S. Grover, “Esti-mation of Quality for Software Components: an Empiri-cal Approach”, ACM SIGSOFT Software Engineering Notes, Vol. 33, Issue.6, pp.1-10, 2008.

[10] Changli Sun, “Software Documents Quality Measurement- A Fuzzy Approach”.

[11] Avadhesh Kumar,P.S. Grover,Rajesh Kumar, “A Quantitative Evaluation of Aspect-Oriented *Software Quality Model (AOSQUAMO)*”, September 2009 Volume 34 Number 5.

[12] X.Cai, M.R. Lyu, K. Wong, Component Based Soft-ware Engineering: Technologies, Development Frameworks, and Quality Assurance Schemes, Pro-ceedings APSEC 2000, Seventh Asia-Pacific SoftwareEngineering Conference, Singapore, December 2000, pp 372-379.

[13] Zadeh LA (1965) Fuzzy sets. Inf Control 8:338,353.

[14] Bojadziev G, Bojadziev M (1998) Fuzzy sets and fuzzy logic applications. World Scientific, Singapore.

[15] Ertuğrul İ, Tuş A (2007) Interactive fuzzy linear programming and an application sample at a textile firm. Fuzzy Optim Decis Making 6:29–49.

[16] Zimmermann HJ (1992) Fuzzy set theory and its applications. Kluwer, Boston.

[17] Deng H (1999) Multicriteria analysis with fuzzy pair-wise comparison. Int J Approx Reason 21:215–231.

[18] Saaty, T. L. (1988). Multicriteria decision making: The analytic hierarchy process. Pittsburgh: RWS Publications.

[19] Saaty, T. L. (1990). How to mark a decision: The analytic hierarchy process. European Journal of Operational Research, 48(1), 9–26.

