Expert Systems with Applications 38 (2011) 12009–12017

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A measurement model for experts knowledge-based systems algorithm using fuzzy analytic network process

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ARTICLE INFO

Keywords:
Knowledge-based systems algorithm
Fuzzy analytic network process (FANP)
Analytic network process (ANP)
Fuzzy multi-attribute decision-making (FMADM)
Digital video recorder system
Software evaluation
System evaluation

ABSTRACT

This study proposes an experts knowledge-based systems measurement model, the model using fuzzy analytic network process (FANP) to resolve the uncertainty and imprecision of evaluations during pre-negotiation stages, where the comparison judgments of a decision maker are represented as fuzzy triangular numbers. A novel fuzzy prioritization method, which derives crisp priorities (criteria weights and scores of alternatives) from consistent and inconsistent fuzzy comparison matrices, is also proposed. The applicability of the proposed model is demonstrated in a government purchase digital video recorder (DVR) system project study. The stability tests indicate the advantages of the proposal model in determining the value of model. Importantly, the proposed model can provide decision makers a reference material, making it highly applicable for academic and commercial purposes.

1. Introduction

Multiple attribute decision making (MADM) is a methodology that helps decision makers building experts knowledge-based systems regarding a finite set of available alternatives (courses of action) characterized by multiple, potentially conflicting criteria or attributes (Belton & Stewart, 2002; Mollaghasemi & Pet-Edwards, 1997). MADM provides a formal framework for modeling multi-attribute decision problems, particularly problems whose nature demands systematic analysis, including analysis of decision complexity, regularity, significant consequences, and the need for accountability (Belton & Stewart, 2002). MADM provides a formal framework for modeling multi-criteria decision problems, particularly problems demanding a systematic analysis, including analysis of the decision complexity, regularity, significant consequences, and the need for accountability (Belton & Stewart, 2002). Existing experts knowledge-based systems evaluates models which include: (1) The Weighted Sum Model (WSM) (Sobczak and Berry, 2007): In a weighted sum, each element of a sum is multiplied by its weight. (2) Grey Relational Analysis (GRA) Model (Chang, Wu, & Lin, 2008; Chiu, 2009; Huang, Chiu, & Chen, 2008; Lin, Wang, Wu, & Chuang, 2009): The concept of gray relational space was proposed by Deng based on the combined concepts of system theory, space theory and control theory. It can be used to capture the correlations between the references factor and other compared factors of a system (Deng, 1989). (3) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Model (Celik, Cebi, Kahraman, & Er, 2009; Dagdeviren, Yavuz, & Kılınç, 2009; Li, Wang, Liu, & Shan, 2008; Tsou, 2008): TOPSIS is based on the concept that the most preferred alternative should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution (Yoon & Hwang, 1995). (4) Analytic Hierarchy Process (AHP) Model (Jose & Ines, 2005; Kolat, Doyuran, Can Ayday, & Süzen, 2006; Sobczak and Berry, 2007; Hsu & Pan, 2009; Li & Li, 2009; Wang & Yang, 2007): AHP is also a measurement theory that prioritizes the hierarchy and consistency of judgmental data provided by a group of decision makers. AHP incorporates the evaluations of all decision makers into a final decision, without having to elicit their utility functions on subjective and objective criteria, by pair-wise comparisons of the alternatives (Saaty, 1980). (5) Analytic network process (ANP) model (Chang et al., 2007; Lee & Kim, 2001; Lee, Kim, Cho, & Park, 2009; Lin & Tsai, 2009): ANP was expanding AHP, ANP allows for more complex interrelationships among decision levels and attributes (Saaty, 1996).

MADM has thus been successfully applied to a diverse array of problems. Despite its popularity, MADM cannot adequately resolve the inherent uncertainty and imprecision associated with the mapping of an expert or decision maker's perception to exact numbers. In the traditional formulation of MADM, human judgment is represented as exact numbers. Fuzzy multi-criteria decision making (FMADM) methods have been developed owing to the imprecision in assessing the relative importance of attributes and the performance ratings of alternatives with respect to attributes.

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doi:10.1016/j.eswa.2010.12.144

Imprecision may arise from a variety of reasons: unquantifiable information, incomplete information, unobtainable information and partial ignorance. Conventional MADM methods cannot effectively handle problems with such imprecise information (Chang, Wu, & Lin, 2009). To resolve this difficulty, fuzzy set theory, first introduced by Zadeh (1965), has been used and is adopted herein. Fuzzy set theory attempts to select, prioritize or rank a finite number of courses of action by evaluating a group of predetermined criteria (Chen, Lin, Wang, & Chang, 2006; Moon and Lee, 2005). Solving this problem thus requires constructing an evaluation procedure to rate and rank, in order of preference, the set of alternatives.

This study proposes an experts knowledge-based systems measurement model, the model using fuzzy analytic network process (FANP) to resolve the uncertainty and imprecision of evaluations during pre-negotiation stages, where the comparison judgments of a decision maker are represented as fuzzy triangular numbers. A novel fuzzy prioritization method, which derives crisp priorities (criteria weights and scores of alternatives) from consistent and inconsistent fuzzy comparison matrices, is also proposed. The applicability of the proposed model is demonstrated in a government purchase digital video recorder (DVR) system project study. The stability tests indicate the advantages of the proposal model in determining the value of model. Importantly, the proposed model can provide decision makers a reference material, making it highly applicable for academic and commercial purposes.

2. Fuzzy analytic network process

Fuzzy multi-criteria decision making (FMCDM) methods had been developed owing to the imprecision in assessing the relative importance of attributes and the performance ratings of alternatives with respect to attributes. Imprecision may arise from a variety of reasons: unquantifiable information, incomplete information, unobtainable information and partial ignorance. Conventional MCDM methods cannot effectively handle problems with such imprecise information. To resolve this difficulty, fuzzy set theory, first introduced by Zadeh (1965), has been popularly used and is adopted herein. Fuzzy set theory attempts to select, prioritize or rank a finite number of courses of action by evaluating a group of predetermined criteria. Solving this problem thus requires constructing an evaluation procedure to rate and rank, in order of preference, the set of alternatives.

The ANP of Saaty (1996) only uses the pair-wise comparison matrix to evaluate the ambiguity in multi-criteria decision making problems as in formula (1). Assume that we have n different and independent criteria $(C_1, C_2, \ldots, C_n)$ and they have the weights $(W_1, W_2, \ldots, W_n)$, respectively. The decision-maker does not know in advance the values of W_i, $i = 1, 2, \ldots, n$, but he is capable of making pair-wise comparison between the different criteria. Also, assume that the quantified judgments provided by the decision-maker on pairs of criteria (C_i, C_j) are represented in an $n \times n$ matrix as in the following:

$$A = [aij] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \vdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \end{array}, \tag{1}$$

where $a_{ii} = 1$ and $a_{ji} = \frac{1}{aij}$, $i, j = 1, 2, \ldots, n$.

This study combines ANP and extends the notions of Buckley (1985) to analyze data and reach a consensus among experts. This process of FANP comprises four major steps as follows:

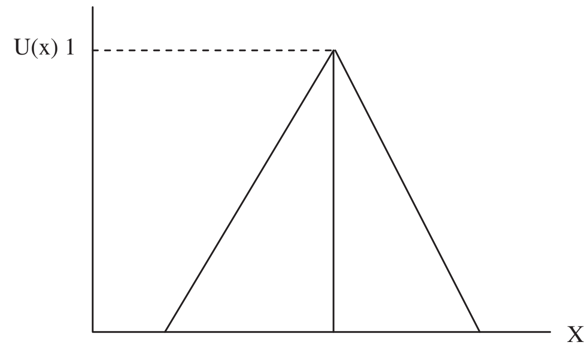

Fig. 1. Triangular fuzzy numbers.

2.1. Step 1: Establish model and problem

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

2.2. Step 2: Establish the triangular fuzzy numbers

Saaty (1980) contended that the geometric mean accurately represents the consensus of experts and is the most widely used in practical applications. Here, geometric mean is used as the model for 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 was its capability of representing vague data. The theory also allows mathematical operations and programing to apply to the fuzzy domain. 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. A triangular fuzzy number (TFN) is shown in Fig. 1.

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. A TFN is denoted simply as (L, M, U). The parameters L, M and U, respectively, denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event as shows in formulae (2)–(5).

The triangular fuzzy numbers $\tilde{u}_i j$ are established as follows:

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

$$L_{ij} \leqslant M_{ij} \leqslant U_{ij} \quad \text{and} \quad L_{ij}, M_{ij}, U_{ij} \in [1/9, 9],$$

$$L_{ij} = \min(B_{ijk}), \tag{3}$$

$$M_{ij} = \sqrt[n]{\prod\nolimits_{k=1}^{n} B_{ijk}}, \tag{4}$$

and

$$U_{ij} = \max(B_{ijk}), \tag{5}$$

where B_{ijk} represents a judgment of expert k for the relative importance of two criteria C_i–C_j.

2.3. Step 3: Establish the fuzzy pair-wise comparison matrix (independent and interdependent) and defuzzification

$$\widetilde{A} = [\tilde{a}_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \frac{1}{\tilde{a}_{12}} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{1}{\tilde{a}_{1n}} & \frac{1}{\tilde{a}_{2n}} & \cdots & 1 \end{bmatrix} \end{array}, \tag{6}$$