Choquet integral-based hierarchical networks for evaluating customer service perceptions on fast food stores

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Abstract

It is known that a hierarchical decision structure consisting of multiple criteria can be modeled by a Choquet integral-based hierarchical network. With a given input–output dataset, the degree of importance of each criterion can be directly obtained from the corresponding connection weight after the network has been trained from samples. Since each output value or the synthetic evaluation of an alternative derived from uncertain assessments has its upper and lower bounds, the degree of importance of each criterion should not be unique and can be distributed in a range. In this paper, the range of the degree of importance of each criterion is obtained by three Choquet integral-based hierarchical networks with the pre-specified hierarchical structure: one is a common network constructed by merely minimizing the least squared error, and the others are employed to determine a nonlinear interval regression model. The above three networks are trained with a given input–output dataset using the proposed genetic algorithm-based learning algorithm. Empirical results of evaluating customer service perceptions on fast food stores demonstrate that the proposed method can identify key factors that have stronger effect on service quality perceptions by employing three Choquet integral-based hierarchical networks with the hierarchical structure to determine possible ranges of the degree of importance of respective aspects and attributes.

1. Introduction

A decision problem can be evaluated by a hierarchical structure consisting of diverse criteria. The hierarchy decomposes from the general goal to more specific attributes until a level of manageable decision criteria is met (Meade & Presley, 2002). As depicted in Fig. 1, the given hierarchical structure is usually composed of three decision levels including the objective, the aspects, and the attributes. To obtain the synthetic evaluation of an alternative, the weighted average method (WAM) with the additivity assumption is usually taken into account. In practice, the additive WAM is performed on the objective and each aspect assuming that there is no interaction among the attributes towards the objective attribute (Murofushi & Sugeno, 1989, 1991, 1993; Sugeno, Narukawa, & Murofushi, 1998; Tseng & Yu, 2005). Many well-known scoring methods with additive property, such as the Analytical Hierarchy Process (AHP) (Saaty, 1994), the Delphi method, the eigenvector method, the weighted least square method, the entropy method, SMARTS, SMARTER (Edwards & Barron, 1994), a weight-assessing method with habitual domains (Tseng, Chen, & Wang, 1998), as well as the linear programming techniques for multi-dimensions of analysis preference (LINMAP), can be employed to find the degree of importance of respective criteria. For the above methods, the sum of degree of importance of respective criteria is assumed to be just one.

Unfortunately, the additivity assumption is not warranted in many real-world problems (Wang, Leung, & Kli, 2005; Wang, Wang, & Kli, 1998). Instead, the fuzzy measure can be employed to describe the interaction among the attributes in a set. Once a nonadditive fuzzy measure is employed to express the importance of relevant attributes towards the objective attribute, the synthetic evaluations of individual alternatives can be obtained by a nonadditive data mining technique, the Choquet integral (Murofushi & Sugeno, 1989, 1991, 1993; Sugeno et al., 1998), rather than the additive techniques such as WAM (Wang et al., 2005). In view of the nonadditive property, the Choquet integral has been widely applied to multiple-criteria decision-making (MCDM) (Chiou & Tzeng, 2002; Chen, Wang, & Tzeng, 2000; Jeng, Chuang, & Su, 2003; Kwak & Pedrycz, 2004; Tzeng, Ou Yang, Lin, & Chen, 2005; Tseng & Yu, 2005; Wang, Leung, et al., 2005; Tsai & Lu, 2006). In particular, Chiang (1999) introduced the structure of the Choquet integral-based hierarchical network, which can be regarded as a fuzzy neural network, and demonstrated the effectiveness of the network for nonlinear mappings. The advantage of the Choquet integral-based hierarchical network is that, when the synthetic...
2. Choquet integral-based hierarchical decision

A hierarchy is usually employed to model a decision problem. Since the additive assumption is not realistic in many applications, it is reasonable to use the nonadditive Choquet integral with respect to a fuzzy measure, instead of the most common WAM with respect to a classical additive measure (e.g., the probabilistic measure), as an aggregation tool in the objective and each aspect in Fig. 1. In this section, the identification of the interaction among criteria by a fuzzy measure is presented in Section 3.1. In Section 3.2, the Choquet integral performed in the CINHSs is described.

2.1. Identification of the interaction among attributes

Let \( X \) denote a finite set of \( \{x_1, x_2, \ldots, x_n\} \). A fuzzy measure \( \mu(P(X)) \rightarrow [0, 1] \) is nonadditive set function that satisfies the following properties (Chen, Chang, & Tzeng, 2002; Sugeno, 1974, 1977; Wang & Klir, 1992):

1. \( \mu(\emptyset) = 0, \mu(X) = 1 \) (boundary conditions);
2. for \( \forall A, B \in P(X) \), if \( A \subset B \), then \( \mu(A) \leq \mu(B) \) (monotonicity),

where \( P(X) \) denotes the power set of \( X \). In comparison with the additive measure, the fuzzy measure with the monotonicity assumption considers the interrelation between attributes by expressing importance of relevant attributes towards the objective attribute (Chen et al., 2002; Tseng & Yu, 2005; Tzeng et al., 2005). For instance, \( \mu(x, x_j) \) represents the combined grade of importance of \( \{x, x_j\} \). Owing to the nonadditive property of \( \mu, \mu(x, x_j) \) is usually not equal to \( \mu(x) + \mu(x_j) \). In particular, if \( \mu(x, x_j) = 0 \), then \( x_j \) is viewed as a redundant attribute (Brady, Voorhees, Cronin, & Bourdeau, 2006).

Fuzzy measures can be used with the Choquet integral for aggregating information sources. Among diverse fuzzy measures, the \( \lambda \)-fuzzy measure has been suggested for computing the fuzzy integral for its convenience and feasibility (Kuncheva, 2000; Wang & Wang, 1997). For all \( A, B \in P(X) \) with \( A \cap B = \phi \), \( \mu \) is a \( \lambda \)-fuzzy measure satisfying the following property:

\[
\mu(A \cup B) = \mu(A) + \mu(B) + \lambda \mu(A) \mu(B), \quad \lambda \in (-\infty, \infty)
\]  

(1)

where \( \lambda \) is found from \( \mu(A) = 1 \). The value of \( \mu \) for any subset \( A \) can be obtained by the values of \( n \) fuzzy densities (i.e., \( \mu(x_1), \ldots, \mu(x_n) \)) as follows:

\[
\mu(A) = \frac{1}{|A|} \prod_{x \in A} \left( 1 + \lambda \mu(x) \right) - 1
\]  

(2)

The characteristic of the \( \lambda \)-fuzzy measure is that \( \mu \) can be uniquely determined by \( \mu(x_1), \ldots, \mu(x_n) \).

The interaction among \( x_1, \ldots, x_n \) can be identified by the value of \( \lambda \).
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