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Cluster analysis based on fuzzy equivalence relation

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Abstract

In this paper, a cluster analysis method based on fuzzy equivalence relation is proposed. At first, the distance formula between two trapezoidal fuzzy numbers is used to aggregate subjects' linguistic assessments about attributes ratings to obtain the compatibility relation. Then a fuzzy equivalence relation based on the fuzzy compatibility relation can be constructed. Finally, using a cluster validity index to determine the best number of clusters and taking suitable λ-cut value, the clustering analysis can be effectively implemented. By utilizing this clustering analysis, the subjects' fuzzy assessments with various rating attitudes can be taken into account in the aggregation process to assure more convincing and accurate cluster analysis.

Keywords: Fuzzy sets; Fuzzy cluster analysis; Linguistic value; Equivalence relation; Strategic group

1. Introduction

Cluster analysis is a very useful classification tool. It has been used frequently in product position, strategy formulation, market segmentation studies and business system planning [1–3]. In disjoint cluster analysis, the object, e.g. a brand in product positioning studies or a strategy in business operation studies, is identified as a member of one and only one cluster. It emphasizes the mutually exclusive and exhaustive nature of the cluster development [1,3]. Indeed, objects may well fit into several clusters, e.g. brands can compete against more than one competitive set as well as consumers can belong to more than one segment. To relax the exclusivity constraint of disjoint cluster analysis, Arabie et al. [2] proposed an overlapping

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clustering model. Their approach can be used in marketing studies involving products/objects that can belong to more than one group or cluster simultaneously.

To effectively reflect the fuzzy phenomenon existing in clustering analysis, fuzzy set theory [4–6] was utilized to tackle clustering problem [5–15]. Fuzzy clustering methods have been developed widely in the last 20 years. The first fuzzy clustering method was presented by Dunn [5]. Then, Bezdek [6] developed the fuzzy c-means (FCMs) clustering algorithm to classify each object into clusters with different or same degree of membership based on the assumption that the desired cluster number is given and the minimization of an objective function. To overcome the drawback of the FCMs method that only considered the homogeneity within cluster and ignored the well-separated property, Wang et al. [10] proposed a bi-criteria FCMs method to deal with clustering problem. The FCMs-based methods required that the desired numbers must be specified. This is a disadvantage whenever the desired number does not be determined in a clustering problem. Lee [13] proposed a hierarchical clustering algorithm to cluster the business processes identified in the step of business systems planning. And a matching approach was presented to determine the best number of clusters. Klir and Yuan [11] presented a fuzzy equivalent relation-based hierarchical clustering method to deal with the cluster problem in which the desired number of clusters does not be specified. Groenen and Jajuga [15] developed a fuzzy clustering model based on a root of the squared Minkowski distance with includes squared and unsquared Euclidean distance and L_1-distance. This method can be used to reconstruct clusters from error perturbed data. All the methods stated above are based on the concept of accurate measure and crisp evaluation.

In real life, due to the availability and uncertainty of information as well as the vagueness of human feeling and recognition, it is difficult to exactly evaluate and convey the feeling and recognition of objects against the character of various brands/products or the degree of attention customer have to various management strategies, e.g. the loyalty of customers and the attention of customers' satisfaction. Hence, the precision-based cluster analysis may not be practical. Besides, the data evaluation of the objects feeling toward versus brands/products, as well as the degree of attention management strategies are often expressed in linguistic terms, e.g. "very low", "between very poor and poor", "fair", "very high", "about \$9000", "approximately between \$56,000 and \$64,000", etc. It seems that a fuzziness-based method is needed to integrate various linguistic assessments about attributes ratings and construct the fuzzy cluster analysis.

Since the approximate reasoning of fuzzy set theory can also be used to represent linguistic values [16], to effectively handle the ambiguities involved in the evaluation data and the vague property of linguistic expressions, the trapezoidal fuzzy numbers are used to characterize fuzzy measures of quantitative data and denote the approximate reason of linguistic values [16–18]. Furthermore, a cluster method based on fuzzy equivalence relation is presented to tackle the cluster analysis under fuzzy environment.

To effectively utilize the limited resource and core competence, seeking out the advantageous position over the competition are very important issue in business management [19]. Strategic group is a group of companies that follow the same strategy to establish a major decision action [20–22]. A decision maker of a company does not pick any type of strategy to learn blindingly. They must understand the core ability and financial ability of their own companies and to follow or to learn the competitor behavior in the same group with similar character. Owing to the change of industrial structure, the type of product mixes changes from large size to precision, small volume and high unit price. Since the request for high technical products logistics is low storage and quick delivery, it assists the fast development of airfreight industry in Taiwan, and cause intense competition in airfreight forwarder market. So, to develop a practical cluster analysis algorithm for discriminating strategy a group analysis is important and helpful for airfreight forwarder decision maker. At the end of this paper, authors will have a empirical example of Taiwan airfreight forwarder for the clustering and analyzing current operation strategies.