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On multi-period multi-attribute decision making

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Abstract

Multiple attribute decision making (MADM) is an important part of modern decision science. It has been extensively applied to various areas such as society, economics, military, management, etc., and has been receiving more and more attention over the last decades. To date, however, most research has focused on single-period multi-attribute decision making in which all the original decision information is given at the same period, and a number of methods have been proposed to solve this kind of problems. This paper is devoted to investigating the multi-period multi-attribute decision making (MP-MADM) problems where the decision information (including attribute weights and attribute values) are provided by decision maker(s) at different periods. We define the concept of dynamic weighted averaging (DWA) operator, and introduce some methods, such as the arithmetic series based method, geometric series based method and normal distribution based method, to obtain the weights associated with the DWA operator. Based on the DWA operator, we develop an approach to MP-MADM. Moreover, we extend the DWA operator and the developed approach to solve the MP-MADM problems where all the attribute values provided at different periods are expressed in interval numbers, and use a possibility-degree formula to rank and select the given alternatives.
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1. Introduction

Multiple attribute decision making (MADM) involves finding the most desirable alternative(s) from a discrete set of feasible alternatives with respect to a finite set of attributes. MADM has been being a hot research topic over the last decades, and has been extensively applied to various areas such as society, economics, military, management, etc. [1–10]. A lot of studies have been done on single-period MADM, for example, Saaty [1] used 1–9 ratio scale to compare each pair of attributes (alternatives) so as to construct a multiplicative preference relation, from which the eigenvalue method is used to derive the attribute (alternative) weights, and finally he aggregated these weights of attributes and alternatives by using the weighted averaging operator to get the ranking of alternatives.

Hwang and Yoon [2] introduced a technique for order performance by similarity to ideal solution (TOPSIS), one of the known classical method for MADM. The fundamental idea of the TOPSIS is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. In the process of TOPSIS, the attribute values and the attribute weights are given as exact numerical values. Chen [11] extended the TOPSIS to the fuzzy environment in which the rating of each alternative and the weight of each attribute are described by linguistic terms which can be expressed in triangular fuzzy numbers. A vertex procedure was developed to calculate the distance between two triangular fuzzy numbers, and a closeness coefficient was defined to determine the ranking of all alternatives by calculating the distances to both the fuzzy positive-ideal solution and fuzzy negative-ideal solution simultaneously. Park and Kim [12] presented the characteristic of weak dominance and proposed dominance graph, and also presented

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an algorithm, by using a separable linear program technique based on linear-(in)equality-styled information, to derive the most preferable alternative(s). Kim et al. [13] presented an interactive procedure for multiple attribute group decision making problems with incomplete information. The procedure needs each group member to express his/her preference in relation to an additive value model with incomplete preference statements, and calculates group's utility range based on each group member's incomplete information. They also described theoretic models for establishing group's pairwise dominance relations with group's utility ranges by using a separable linear programming technique. Ma [14] et al. utilized the subjective information provided by a decision maker and the objective information to establish a two-objective programming model to determine the attribute weights, and then utilized the simple additive weighting method to rank alternatives. Xu and Chen [15] developed an interactive method for solving multiple attribute group decision making problems under fuzzy environments. The method can be used in situations where the information about attribute weights is partly known and the decision maker weights are expressed in exact numerical values or triangular fuzzy numbers, and the attribute values take the form of triangular fuzzy numbers. Chen and Hwang [4] proposed a method for fuzzy MADM problems. The approach first converts the fuzzy decision data (linguistic terms or fuzzy numbers) into crisp scores, and then applies an appropriate classical MADM method (such as TOPSIS, etc.) to determine the ranking of alternatives. It is capable of solving large size real-world problems which contain a mixture of fuzzy and crisp data. Brans and Vincke [16] presented a preference ranking organization method for enrichment evaluations (PROMETHEE I) to build a partial ranking among alternatives, and proposed an enhanced method, PROMETHEE II, which allows ranking all alternatives, including incomparable ones, to obtain a total classification. Pawlak et al. [17–19] applied rough set theory to multi-attribute decision analysis and developed some rough set based approaches to solving the MADM problems. Xu and co-workers [20,21] developed two evidential reasoning approaches to multi-attribute decision analysis under uncertainty and interval uncertainty, respectively. Yager [22] introduced the concept of ordered weighted averaging (OWA) operator, whose fundamental characteristic is the re-ordering step, in particular, an argument is not associated with a particular weight, but rather a weight is associated with a particular ordered position of the arguments. Then, he used the OWA operator to aggregate the decision information expressed in exact numerical values in MADM. Bordogna et al. [23] established a linguistic model based on linguistic OWA operators to evaluate the consensual judgment and consensus degree for each alternative in multiple attribute group decision making, where both the decision makers' evaluations of the alternatives and the degree of consensus are expressed linguistically. Xu [24] proposed the uncertain linguistic ordered weighted averaging

(ULOWA) operator and uncertain linguistic hybrid aggregation (ULHA) operator, and then based on these two operators, developed an approach to multiple attribute group decision making with uncertain linguistic information. Fenton and Wang [25] investigated the MADM problems taking account of uncertainty, risk and confidence. They used linguistic variables and triangular fuzzy numbers to model the decision maker's risk and confidence attitudes in order to define a more complete MCDM solution, and employed a practical travel problem to assess the developed MCDM technique. This technique is useful for tackling imprecision and subjectivity in complex, ill-defined and human-oriented decision problems. Xu [26] explored the MADM problems with linguistic information, in which the information about attribute weights is incompletely known, and the attribute values take the form of linguistic variables. Xu introduced some approaches to obtaining the weight information of attributes, and then established an optimization model based on the ideal point of attribute values, by which the attribute weights can be determined. Furthermore, Xu utilized the numerical weighting linguistic average (NWLA) operator to aggregate the linguistic variables corresponding to each alternative and ranked the alternatives by means of the aggregated linguistic information, and then applied the developed method to the ranking and selection of propulsion/manoeuvring system of a double-ended passenger ferry.

However, in many real-life situations, such as multi-period (multi-stage) investment decision making, medical diagnosis, personnel dynamic examination, and military system efficiency dynamic evaluation, etc., the original argument information may be collected from different periods. Thus, it is an interesting and important research issue. In this paper, we shall focus on this issue and organize this paper in six sections. Section 2 defines the concept of dynamic weighted averaging (DWA) operator, and introduces some methods to determine the weights associated with the DWA operator. Based on the DWA operator, Section 3 develops an approach to solving the MP-MADM problems where all the attribute values at different periods are expressed in exact numerical values. Section 4 extends the DWA operator and the developed approach to solve the MP-MADM problems where all the attribute values provided at different periods are expressed in interval numbers. Section 5 gives an illustrative example, and Section 6 ends the paper.

2. Dynamic weighted averaging (DWA) operator

Information aggregation is a key step in the process of MADM. At present, many aggregation operators have been developed to aggregate argument information [27]. As was pointed out in [28], current research on aggregation operators mainly focuses on time independent operators. Accordingly, as time is not taken into account, operators and weights are usually kept constant. However, in many real-life situations, the argument information may be provided at different periods (stages). Thus, it is necessary to