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Visual information feedback mechanism and attitudinal prioritisation method for group decision making with triangular fuzzy complementary preference relations

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ABSTRACT

A visual information feedback mechanism for group decision making (GDM) problems with triangular fuzzy complementary preference relations (TFCPRs) is investigated. The concepts of similarity degree (SD) between two experts as well as the proximity degree (PD) between an expert and the rest of experts in the group are developed for TFCPRs. The consensus level (CL) is defined by combining SD and PD, and a feedback mechanism is proposed to identify experts, alternatives and corresponding preference values that contribute less to consensus. The novelty of this feedback mechanism is that it will provide each expert with visual representations of his/her consensus status to easily 'see' his/her consensus position within the group as well as to identify the alternatives and preference values that he/she should be reconsidered for changing in the subsequent consensus round. The feedback mechanism also includes individualised recommendation to those identified experts on changing their identified preference values and visual graphical simulation of future consensus status if the recommended values were to be implemented. Based on the continuous ordered weighted average (COWA) operator, the triangular fuzzy COWA (TF-COWA) operator is defined, and a novel attitudinal expected score function for TFCPRs is developed. The advantage of this function is that the alternatives are ranked by taking into account the attitudinal character of the group of experts or its moderator if applicable. Additionally, a ranking sensitivity analysis of the attitudinal expected score function with respect to the attitudinal parameter is provided.

1. Introduction

Preference relations, also known as pairwise comparison matrices, are a popular and powerful method to model experts' preferences in group decision making (GDM) problems. The main advantage of preference relations is that individuals can focus exclusively on two alternatives at a time, which facilitates the expression of their opinions [29] and then makes them more accurate than non-pairwise methods [45].

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In classical decision making systems, given an ordered pair of alternatives, the set of numerical values $\{1, 0.5, 0\}$, or its equivalent $\{1, 0, -1\}$ [21,22], is used to represent the following three preference states: (i) the first alternative is preferred to the second one; (ii) both alternatives are considered equally preferred (indifference); and (iii) the second alternative is preferred to the first one, respectively. This numeric discrimination model of preferences is the simplest possible and it proves insufficient in decision making situations where the implementation of 'intensity of preference' between alternatives is necessary [1,13,20].

The concept of fuzzy set when applied to a classical relation leads to the concept of a fuzzy relation, which in turn allows the implementation of intensity of preferences [73]. In this approach, the numeric scale used to evaluate intensity of preferences is the continuum set $[0, 1]$ [2,8,10,12,32,36,48,56,61,64,68]. An alternative and isomorphic numeric scale [11], $[1/9, 9]$, used when the valuations are measured by a ratio scale, rather than a difference scale as in the previous case, is also possible and widely studied in literature [4,41,47,65]. Interval extensions of these two types of numeric preference relations have also been developed [5,19,24,39,40,52,55,57,60].

Subjectivity, imprecision and vagueness in the articulation of opinions pervade real world decision applications, and individuals usually find it difficult to evaluate their preference using exact numbers [73]. Individuals might feel more comfortable using words by means of linguistic labels or terms to articulate their preferences [74]. Furthermore, humans exhibit a remarkable capability to manipulate perceptions and other characteristics of physical and mental objects, without any exact numerical measurements and complex computations [17,42,43,46,58,69,75].

The main two methodologies to represent linguistic preference relations (LPRs) in decision making are [27]: (i) the *cardinal* representation model based on the use of fuzzy sets and their associated membership functions, which are mathematically processed using Zadeh's *extension principle* [73] and (ii) the *ordinal* representation model by means of the *2-tuples methodology* [28,30,66]. Although the later representation is able to capture some of the linguistic information to model, it is in fact processed using mathematical tools that are not appropriate for ordinal information but for information provided using a difference or ratio scale. Evidence of this is that the ordinal linguistic model is mathematically equivalent to the cardinal approach with fuzzy sets represented using a representative element of its membership function, and example of which is the centroid. Therefore, the uncertainty nature of the information is lost in the ordinal linguistic computational model. Furthermore, the linguistic cardinal approach is richer than the ordinal linguistic approach, not only because it has the latter one as a particular case, but also because it provides a more flexible tool for GDM with LPRs in which: (1) the experts and/or moderator attitudinal character can be implemented in the decision making process and (2) different types of fuzzy sets are possible to be used depending on the type and intensity of the imprecision and vagueness contained in the linguistic information to model. In particular, the use of triangular fuzzy sets to model linguistic information, which leads to the so-called triangular fuzzy complementary preference relations (TFCPRs) [15,49,51,53,54,63] are worth investigating because they extend both numeric preference relations and interval-valued preference relations. This paper focuses on the use of this type of linguistic preference relation to formulate a framework for GDM problems.

GDM problems generally involve situations of conflict among its experts, and therefore it is preferable that the set of experts reach consensus before applying a selection process to derive the decision solution. There are two basic consensus models in GDM: the static consensus models [6,23,37,70,76] and the interactive consensus models [3,9,33,34,62]. The former does not implement any type of feedback mechanism to advice experts on how to change their preferences in order to achieve a higher consensus level while the later does. Existing interactive consensus models methodology relies on the imposition to decision makers (DM) of changes in their opinion when consensus is below a threshold value. However, in practice, it is up to the decision maker to implement or not the recommendations given to him/her [18]. A more reasonable and suitable policy should rest on this premise and, consequently, it would allow the DM to revisit his/her evaluations using appropriate and meaningful consensus information representation. Therefore, the aim of this article is to propose a visual information feedback mechanism for GDM to provide each expert with visual representations of his/her consensus status to easily 'see' his/her consensus position within the group as well as to identify the alternatives and preference values that he/she should be reconsidered for changing in the subsequent consensus round. The feedback mechanism also includes individualised recommendation to those identified experts on changing their identified preference values and visual graphical simulation of future consensus status if the recommended values were to be implemented. To achieve this, a first objective of this paper is to extend Hsu and Chen's similarity degree (SD) [35] to the case of TFCPRs to measure, in the unit interval, how close two individual experts are. The proximity of an expert with respect to the whole group of experts is also measured, resulting in individual proximity degree (PDs). Consensus level (CLs) is defined as a linear combination of SDs withPDs, and all will be defined at the three different levels of a preference relation: the pairs of alternatives, the alternatives and the whole set of alternatives.

An additional limitation of the above consensus models is that they do not take into account the risk attitude of decision makers in the prioritisation process. Therefore, they are not rich enough to capture all the information contained in TFCPRs. Therefore, a second objective of this paper is to define a new prioritisation method for TFCPRs. In the case of interval-valued preference relations, we can find proposals based on their transformation to numeric preference relations by the continuous interval argument ordered weighted average (C-OWA) operator [67,71,72]. In [59], the interval-valued intuitionistic fuzzy COWA (IVIF-COWA) operator, which is also used to derive numeric preference relations, is investigated. The advantage of these methods is that ranking of the alternatives is obtained by taking into account the expert's attitudinal character. Recall that interval numbers are particular case of triangular fuzzy numbers, and therefore this link allows us to motivate the definitions of the triangular fuzzy COWA (TF-COWA) operator and its associated attitudinal expected score function. The

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