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Managing experts behavior in large-scale consensus reaching processes with uninorm aggregation operators

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ABSTRACT

In many real-life large scale group decision making problems, it can be necessary and convenient a consensus reaching process, which is an iterative procedure aimed at seeking a high degree of agreement amongst experts' preferences before making a group decision. Although a wide variety of models and approaches have been proposed and developed to support consensus reaching processes, in large groups there are some important aspects that still require further study, such as the treatment of experts' behaviors that could hamper reaching the wanted agreement. More specifically, it would be necessary an approach to deal with experts properly, based on the overall behavior they present during the discussion process, as well as reinforcing repeated patterns of cooperative (or uncooperative) behavior adopted by experts. This paper presents an expert weighting methodology for consensus reaching processes in large-scale group decision making, that incorporates the use of uninorm aggregation operators. Such operators, which are characterized by their property of full reinforcement, are used in the proposed methodology to allow the experts' weighting based on their overall behavior during the consensus process and the behavior evolution across the time. This proposal is integrated in a consensus model for large-scale group decision making problems under uncertainty, and it is put in practice to show an illustrative example of its effectiveness and improvements with respect to other approaches.

1. Introduction

Decision making is a frequent process in human daily lives, in which there exist several alternatives and the best one/s shall be chosen. Group decision making (GDM) problems, characterized by the participation of multiple individuals or experts in such a process, have been subject of an extensive research in the last decades [1,2].

In the traditional resolution process for GDM problems [3], each expert provides his/her preferences over alternatives and the best alternative or subset of them is selected, disregarding the degree of agreement between experts' preferences. This often leads to the drawback that some experts may not accept the decision made [4], because they might consider that their opinions have not been heard. For this reason, the study of consensus reaching processes (CRPs), in which experts aim at reaching a collective agreement before making a decision [5], has become a prominent research topic in GDM [6–8]. CRPs are iterative discussion processes in which experts *must* accept a priori to collaborate bringing their opinions closer to each other in order to achieve an agreement [9].

Classically, GDM problems taking place in most organizations occur at a strategic level, in which a small number of people are responsible for making the decision. However, the expansion of technological paradigms such as social media and e-marketplaces, is causing that the so-called large-scale GDM problems [10–12], in which a larger number of experts can take part, attain a greater importance. In CRPs carried out in these contexts, it may occur that some experts or coalitions of them, who may have established a collaboration contract [9], try to break it at some stage in such processes. These experts might refuse to cooperate with the rest of the group to reach an agreement [13] and try to strategically bias the solution for the GDM problem [14], hence it is necessary to identify and deal with these non-cooperative experts' behaviors to ensure a normal CRP development.

Some early proposals to deal with strategic manipulation of preferences in classical GDM problems were proposed by Yager [14,15], where experts' preferences may be penalized before applying the alternatives selection process, by analyzing how drastic

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and biased their opinions are. Later on, an approach focused on consensus-based GDM problems was proposed in [13], where a consensus model for dealing with non-cooperative behaviors of experts in CRPs was presented. Such a model defines a methodology based on fuzzy clustering to identify non cooperating experts and subgroups, and applies a weight-based scheme to penalize them, according to the behavior they presented. In this penalizing scheme, importance weights of experts are updated if they show a non-cooperative behavior only, by penalizing their current value. Nevertheless, the values of experts' weights cannot be increased again, even though they change their mind and decide to adopt a more cooperating attitude from a specific discussion round onwards. Moreover, in [13] the weight updating applied on each expert's preferences at a given discussion round is based on his/her behavior at such a round only, not taking into account neither how his/her behavior was previously nor how it has evolved since the beginning of the CRP. Considering for instance a situation in which two experts present a currently cooperative behavior after four rounds of discussion, they should not be assigned the same importance weight if only one of them has kept cooperating since the beginning of the CRP, and the other one has not cooperated until now.

Regarding the previous cases, making use of the available historical information about experts' behavior in CRPs is, as far as we know, a challenge not properly addressed in this research field yet. If tackled properly, this aspect would allow a more accurate and appropriate management of such behaviors. Nevertheless, there exist several proposals for dynamic multi-criteria decision making in recent literature [16,17], in whose framework the set of alternatives varies over time and each alternative is assessed at multiple time instants (similarly to CRPs for GDM problems, in which experts must provide and revise their assessments over alternatives across several discussion rounds). In these frameworks, a global (dynamic) assessment value for each alternative is computed, so that historical information about previous assessments on that alternative is also considered. For instance, in [16] Campanella and Ribeiro proposed the use of associative aggregation operators to compute global assessments in dynamic multi-criteria decision making scenarios. More specifically, they illustrated the usefulness of uninorm aggregation operators [18,19], due to the interesting properties that they present to reinforce both positive and negative assessments on alternatives at successive time instants.

Inspired by the reinforcement-based aggregation techniques mentioned above to integrate historical information in dynamic decision making approaches, in this paper we propose a uninorm-based methodology for managing non-cooperative behaviors based on the overall behavior of each expert over the course of CRPs in large-scale GDM problems. To do this, we present a weighting scheme based on fuzzy set theory and the methodology of computing with words (CW) [20], that incorporates the use of uninorm aggregation operators, aiming at three goals:

(i) Assigning importance weights to experts based not only on their current behavior, but also on their patterns of behavior presented at previous consensus rounds.
(ii) Such weights are computed based on a linguistic modeling to represent the uncertainty related to the experts' behavior.
(iii) Exploiting the full reinforcement property of uninorm operators to reinforce repeated patterns of cooperative (or non-cooperative) behaviors by an expert at successive rounds.

A consensus model for large-scale GDM under uncertainty that incorporates the proposed weighting scheme is also introduced. Finally, an illustrative example is presented to show the properties of the weighting scheme in practice, as well as its advantages with respect to other consensus approaches.

This paper is set out as follows: in Section 2, some basic concepts about CRPs in GDM, uninorm aggregation operators and CW methodology for reasoning processes are reviewed. Straightaway, Section 3 presents in further detail the uninorm-based weighting scheme for experts in CRPs. A consensus model for managing experts' behaviors that integrates the proposed scheme is then presented in Section 4. Section 5 presents the illustrative example conducted, and some concluding remarks are finally drawn in Section 6.

2. Preliminaries

This section firstly revises some basic concepts about GDM problems and CRPs, followed by an overview of uninorm aggregation operators and the methodology of CW for reasoning processes, both of which are taken into account in the proposal presented in this paper.

2.1. Consensus reaching processes in GDM

GDM entails the participation of multiple experts who must make a collective decision to find a common solution to a problem. Decision processes in which several experts with different knowledge and experience take part, may usually lead to better decisions than those made by just one expert [2].

A GDM problem is formally characterized by the following elements [1]:

- The existence of a common problem to be solved.
- A set $X=\{x_1, \ldots, x_n\}$ $(n \geq 2)$, of *alternatives* or possible solutions to the problem.
- A set $E=\{e_1, \ldots, e_m\}$ $(m \geq 2)$, of individuals or *experts*, who express their opinions or preferences over alternatives X. As previously indicated, this paper focuses on large-scale GDM problems, such that $m \gg 2$.

In order to express their opinions over alternatives, each expert utilizes a preference structure. Fuzzy preference relations are one of the most widely utilized preference structures in many GDM approaches found in [21]. A fuzzy preference relation P_i associated to expert e_i, can be represented for X finite as a $n \times n$ matrix, as follows:

$$P_i = \begin{pmatrix} - & \cdots & p_i^{1n} \\ \vdots & \ddots & \vdots \\ p_i^{n1} & \cdots & - \end{pmatrix}$$

being each numerical *assessment* $p_i^{lk} = \mu_{P_i}(x_l, x_k) \in [0, 1]$, the degree of preference of the alternative x_l over x_k, $l, k \in \{1, \ldots, n\}$, $l \neq k$, according to e_i, such that:

- $p_i^{lk} > 0.5$ indicates e_i's preference of x_l over x_k.
- $p_i^{lk} < 0.5$ indicates e_i's preference of x_k over x_l.
- $p_i^{lk} = 0.5$ indicates e_i's indifference between x_l and x_k.

Fuzzy preference relations can accomplish diverse properties [22–24]. In [25,26], some of these properties have been studied and considered in a consensus model for GDM with fuzzy preference relations. Accordingly, in order to provide or facilitate the construction of consistent preference relations, in this work we assume the reciprocity property in fuzzy preference relations, i.e. assessments accomplish that if $p_i^{lk} = x$, $x \in [0, 1]$, $l \neq k$, then $p_i^{kl} = 1 - x$.