An Adaptive Module for the Consensus Reaching Process in Group Decision Making Problems*

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Abstract. In the group decision making (GDM) framework we deal with decision problems where several decision makers try to achieve a common solution about a problem. In the literature, we can find two processes to carry out before obtaining a final solution: the consensus process and the selection one. The consensus process is a discussion process where the experts change their opinions in order to achieve a high agreement. The selection process searches the solution.
The consensus reaching process is a very important task for GDM problems regarding the necessity that the solution achieved will be assumed and shared by all experts involved in the GDM problem. It consists of several consensus rounds where the experts discuss and change their opinions in order to improve the level of agreement among them.
In this paper, we propose an optimization of the consensus reaching process in GDM problems by means of an adaptive module that applies different procedures to identify the experts' opinions that should be changed according to the level of agreement in each consensus round. Usually at the beginning the agreement is low, so the adaptive module will suggest to many experts to change their opinions. However, after several rounds, the agreement will be higher and hence the number of the changes will be smaller.

Keywords: Consensus, group decision-making, fuzzy preference relation

1 Introduction

In today's business environments, where outside competition is so great, the organizational survival depends on the internal cooperation. The internal cooperation among departments allows to reduce costs and increase the productivity of a company. Research indicates that collective decision making actually produces higher quality decisions than single decision making. So, the role of decision making is changing from a sole expert to teams or group of experts.

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A GDM problem may be defined as a decision making process with two or more experts, $E = \{e_1, e_2, \ldots, e_m\}$ $(m \geq 2)$, characterized by their own perceptions, attitudes and knowledge about the problem, try to choose a common solution from a set of alternatives $X = \{x_1, x_2, \ldots, x_n\}$ $(n \geq 2)$.

To solve a GDM problem are applied two processes to obtain the final solution (see Figure 1):

- *A Consensus process*: It is a discussion process where the experts exchange their opinions in order to reach the maximum agreement about the set of alternatives, X, before making a decision. Normally, this process is guided by the figure of a human moderator [3, 4, 8].
- *A Selection process*: It refers to how to obtain a solution set of alternatives from the opinions provided by the experts. Clearly, it is preferable that the set of experts have a high agreement about the alternatives before applying the selection process.

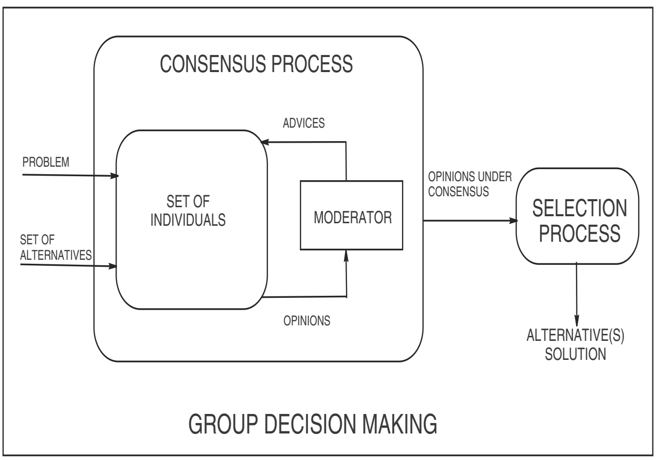

Fig. 1. Resolution process of a group decision-making problem

In this paper, we focus on the consensus process. The consensus is defined as a state of mutual agreement among members of a group where all opinions have been heard and addressed to the satisfaction of the group [11]. The consensus reaching process is defined as a dynamic and iterative process composed of several rounds, where the experts express and discuss about their opinions. Traditionally this process is coordinated by a human moderator, who computes the agreement among experts in each round using different consensus measures [2, 6]. If the agreement is not acceptable (i.e., if it is lower than a specified consensus threshold) then the moderator recommends to the experts to change their furthest opinions from the group opinion in an effort to make their preferences closer in the next consensus round [1, 14].

In the literature, some approaches have been proposed to deal with the consensus reaching process [7, 9, 10, 12, 13]. All these approaches always use the same procedure independently of the level of agreement achieved in the each round. We think that could be more appropriate to use different procedures according to the agreement in each round of the consensus reaching process. So, in the first rounds of the consensus process, the agreement is usually low and it seems logic that many experts should change the most of their opinions. However, after several rounds, the agreement should be higher and then just the furthest experts from the group opinion will change their opinions. Therefore, the procedures ought to be different according to the level of agreement in each round.

In this sense, we propose in this paper to include an adaptive module for the consensus reaching process in GDM problems, such that depending on the level of agreement in each round, it will use a different procedure to identify the experts' opinions that should change to improve the agreement. The goals of this adaptive module are to optimize the consensus reaching process decreasing the number of consensus rounds and the number of changes in experts' opinions.

The rest of the paper is set out as follows. A review of the concept of consensus reaching process is described in Section 2. The features and performance of the adaptive module is presented in Section 3, and finally, in Section 4 we draw our conclusions.

2 The Consensus Reaching Process

In decision making problems where several experts provide their opinions that are usually different. So, it is suitable to carry out a consensus process where the experts exchange their opinions in order to reach a good agreement about the alternatives of the problem before making a decision. In group decision making could happen that some experts may have complaints because their opinions have not been heard when the solution is obtained. Therefore they don't agree with the solution. The consensus reaching process tries that all experts' opinions are taking into account to obtain the solution.

The consensus reaching process is an iterative process where the experts accept to change their opinions following the advice given by the figure of a moderator (see Figure 1). The moderator plays a key role in this process. Normally the moderator is a person that does not participate in the discussion but knows the degree of agreement in each round of the consensus process. He/she is in charge of addressing the consensus process toward success, i.e, to achieve the highest agreement such that the number of experts outside of the consensus will be as small as possible.

To compute the agreement among the experts, it is necessary to measure the similarity among experts' opinions. To do so, the moderator uses two type of measures [5]:

a) *Consensus degrees*. These measures are used to calculate the global level of agreement among the experts' opinions and identify the experts' preferences where exist a great disagreement.

b) *Proximity measures.* These measures evaluate the distance between the experts' individual opinions and the group opinion. They allow to identify the furthest experts' preferences that should be changed.

In [5, 6], different examples of both types of measures for GDM problems, have been proposed.

In GDM problems, the experts usually use preference relations to express their opinions. A preference relation is defined as a matrix $\mathbf{P_{e_i}} = (p_i^{lk})$, where each element p_i^{lk} represents the preference of the alternative x_l on the alternative x_k provided by the expert e_i.

$$\mathbf{P_{e_i}} = \begin{pmatrix} p_i^{11} & \cdots & p_i^{1n} \\ \vdots & \ddots & \vdots \\ p_i^{n1} & \cdots & p_i^{nn} \end{pmatrix}$$

The preference relations allow to compute both consensus degrees and proximity measures at three different levels of representation:

Level 1: *Pairs of alternatives.* In this level both the consensus degree and the proximity (between each individual expert's opinion and the group opinion) on each pair of alternatives are calculated. So, given the preference p_i^{lk} on the pair of alternatives x_l, x_k:
- The consensus degree on that pair of alternatives will be represented as cp^{lk}.
- The proximity of that pair of alternatives for the expert e_i will be represented as pp_i^{lk}.

Level 2: *Alternatives.* In this level, the consensus degree and the proximity on each alternative are obtained. Given the alternative $x_l \in X$:
- The consensus degree on that alternative will be represented as ca^l.
- The proximity of that alternative for the expert e_i will be represented as pa_i^l.

Level 3: P*reference relation or experts.* The global consensus degree among all the experts and the proximity between each individual expert's opinion and the group opinion are calculated.
- The consensus degree among all experts will be represented as cr.
- The proximity of the expert e_i will be represented as pr_i.

Once we have presented the measures to assess the agreement, we show an overall schema of the different phases of a consensus reaching process (see Figure 2).

1. The experts provide their opinions.
2. The consensus measures to measure the agreement among experts are computed.
3. It is checked the level of agreement. If the consensus threshold is achieved, then the consensus reaching process will finish and the selection process will be applied to obtain the solution.

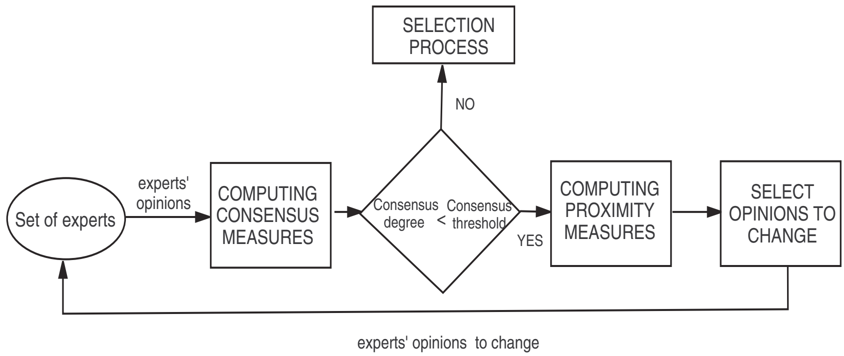

Fig. 2. Phases of the consensus reaching process

4. The proximity measures are computed to measure the distance among individual experts' opinion and group opinion.
5. The experts' opinion that should be changed are selected.

The value of the consensus threshold will depend on each problem and it will be fixed in advance. For instance, a value of 0.8 could be required if the consequences of the decision making are of a significant importance or in other cases a value a little bigger than 0.5 could be enough.

In the literature have been proposed several approaches for the consensus reaching process [9, 10, 12, 13], all of them follow a similar schema to the presented in the Figure 2, in which the process is always the same independently of the agreement in each discussion round. However, we think that the process should be different according to the achieved agreement in the current discussion round, i.e, low consensus implies the search of many values to be changed, however, a higher consensus implies only that search of the furthest experts regarding the group opinion. Therefore, we propose to modify the schema shown in the Figure 2. Such that, the processes after checking the agreement, will be carried out by means of an adaptive module, that according to the current agreement, will apply different operations in order to obtain the experts' opinions that should be changed to improve the agreement in the next discussion round. This scheme is shown in the Figure 3.

In Section 3 we make a detail description of this adaptive module.

3 The Adaptive Module for Consensus Reaching Process

The goal of the adaptive module is to adapt the search of the experts' opinions to change according to the agreement among the experts in each round of the consensus reaching process. To achieve this purpose, we propose that the adaptive module carries out two tasks (see Figure 4):

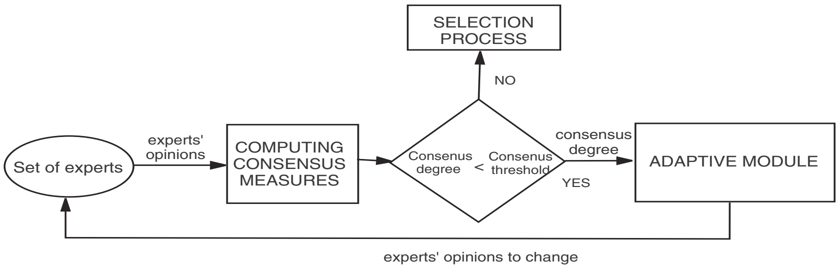

Fig. 3. Adapted consensus reaching process

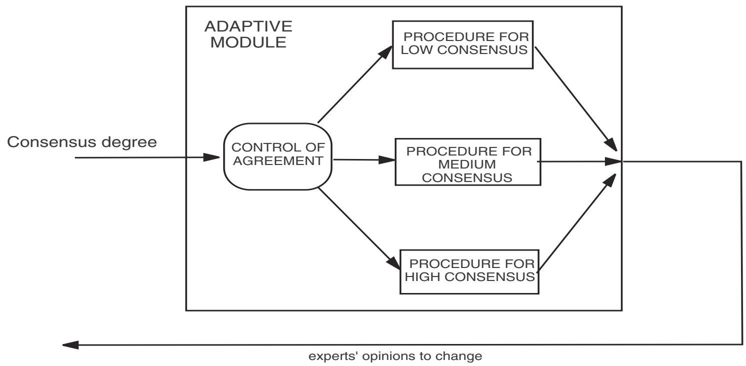

Fig. 4. Adaptive module for the consensus reaching process

1. *Control of agreement.* This module checks the level of agreement or consensus degree among the experts in order to choose a identification procedure to search the opinions to change.
2. *Application of identification procedures.* Depending on the global consensus degree (cr), three different identification procedures have been developed to identify the preferences that should be changed:
   (a) Procedure for low consensus.
   (b) Procedure for medium consensus.
   (c) Procedure for high consensus.
   Each one applies different consensus and proximity criteria to choose the preferences to be changed.

In the next subsections, the details of both tasks are described.

3.1 Control of Agreement

To control the agreement, we need to define rules or selection criteria such that, depending on the consensus degree, will select the appropriate identification procedure. A selection criterion could be the following one:

$$If \quad cr < \gamma \cdot \theta_j \quad Then \ldots$$

where θ_j is a value or percentage used to establish different levels of agreement that imply the different identification procedures to apply, and $\gamma \in [0, 1]$ represents the consensus threshold. In our case, as we propose three identification procedures we will need to define three values, θ_1, θ_2, $\theta_3 = 100\%$. The values of θ_j will depend on type of problem that we are dealing with.

The structure of the algorithm used to control the agreement is shown in the Table 1.

Table 1. Algorithm of control of the level of agreement

```
INPUTS:
        cr, θ1, θ2
BEGIN
        IF cr ≤ γ · θ1
        THEN
                Execute procedure for low consensus
        ELSE
                IF cr ≤ γ · θ2
                THEN
                    Execute procedure for medium consensus
                ELSE
                    Execute procedure for high consensus
                END-IF
        END-IF
END
```

3.2 Application of the Identification Procedures of Preferences

In our module we propose three different procedures to identify the preferences that the experts should to change in order to improve their agreement: procedure for low consensus, procedure for medium consensus, procedure for high consensus.

Each identification procedure analyzes the agreement from different points of view and uses both consensus degrees and proximity measures, as those presented in [3, 6, 8], according to its performance. Furthermore, each identification procedure returns a different set of preferences for each expert e_i, called $PREFECH_i^L$, $PREFECH_i^M$, and $PREFECH_i^H$, respectively. Each one of these sets represents the set of preferences that e_i should change to make their opinions closer to the collective opinion and to improve the agreement.

All identification procedures are described as follows:

Procedure for Low Consensus. This procedure is usually run at the beginning of the consensus process, i.e., when the agreement is low. For instance, we could consider that the agreement is low if the achieved consensus degree is smaller than the half of the wanted consensus threshold, $cr \leq \gamma \cdot \theta_1$, being $\theta_1 = 1/2$. In this situation, the experts' opinions are very different and it will be necessary to propose a lot of changes to improve the agreement.

The purpose of this procedure is to identify all the pairs of alternatives where there exists a high disagreement and suggest *all the experts* to change their preferences on them. In such a way, all the experts change their initial opinions and we avoid that in the first rounds some experts impose their preferences and can address the consensus reaching process toward their own opinions. This circumstance is known as "Tyranny of the Majority" [11].
To do so, the procedure for low consensus carries out the following operations:

1. To compute the consensus degree on all the pairs of alternatives,
$$\{cp^{lk},\ l,k = 1,...,n\}.$$
2. To identify the pairs of alternatives where the agreement is smaller than the specified consensus threshold,
$$M = \{(l,k) \mid cp^{lk} < \gamma\}.$$
3. For each e_i, to compute the set of preferences, $PREFECH_i^L$, that he/she should change to improve the agreement in the next consensus round.
$$PREFECH_i^L = \{p_i^{lk} \mid (l,k) \in M\}$$

Procedure for Medium Consensus. After several consensus rounds the agreement should have improved, for example $\gamma \cdot \theta_1 < cr \leq \gamma \cdot \theta_2$, being $\theta_1 = 1/2$ and $\theta_2 = 2/3$. In this situation, we think that it seems logic to reduce the number of proposed changes.
The purpose of this procedure is only focused on the *alternatives* where exist disagreement, to identify their pairs with smallest agreement and suggest to the furthest experts from the group opinion that change their preferences on those pairs of alternatives.
To do so, the procedure for medium consensus carries out the following operations:

1. To compute the consensus degree on all the pairs of alternatives,
$$\{cp^{lk},\ l,k = 1,...,n\}.$$
2. To compute the consensus degree at the level of alternatives,
$$\{ca^l,\ l = 1,...,n\}.$$
3. To identify the alternatives in which there does not exist agreement,
$$X^M = \{x_l \mid ca^l < \gamma\}.$$
4. For each e_i, to compute the set of preferences, $PREFECH_i^M$. To do that, we use his/her proximity measures computed in the level of pairs of alternatives, pp_i^{lk}, and in the level of alternatives, pa_i^l,
$$PREFECH_i^M = \{p_i^{lk} \mid l \in X^M \wedge pa_i^l < \beta \wedge pp_i^{lk} < \beta\}.$$
being β a proximity threshold.
It is easy to demonstrate that $PREFECH_i^M \subseteq PREFECH_i^L$.

Procedure for High Consensus. If the consensus reaching process is successfully carried out, in the last consensus rounds the agreement will be close to the wanted consensus threshold, e.g., $cr \geq \gamma \cdot 2/3$. In this case, to improve the agreement it is necessary to suggest less changes than in the above identification procedure.

The procedure for high consensus carries out the following operations:

1. To compute the consensus degree on all the pairs of alternatives,
$$\{cp^{lk},\ l,k = 1,...,n\}.$$
2. To compute the consensus degree at the level of alternatives,
$$S\{ca^{l},\ l = 1,...,n\}.$$
3. To identify the alternatives in which there does not exist agreement,
$$X^{M} = \{x_l \mid ca^{l} < \gamma\}.$$
4. For each e_i, to compute the set of preferences, $PREFECH_i^H$. To do that, we use his/her proximity measures computed in the level of pairs of alternatives, pp_i^{lk}, and in the level of alternatives, pa_i^l, and in the level of preference relation, pr_i,
$$PREFECH_i^H = \{p_i^{lk} \mid l \in X^M \wedge pr_i < \beta \wedge pa_i^l < \beta \wedge pp_i^{lk} < \beta\}.$$
being β a proximity threshold.
It is easy to demonstrate that $PREFECH_i^H \subseteq PREFECH_i^M$.

Given that $PREFECH_i^H \subseteq PREFECH_i^M \subseteq PREFECH_i^L$, we should point out that our adaptive module goes looking for to reduce the number of changes to achieve the consensus situation and to get convergent consensus processes.

4 Conclusions

In the GDM problems to achieve consensus solutions is a desirable property. So, before solving a GDM problem could be suitable to develop a consensus process to make experts' preferences closer, such that, the solution obtained presents a high consensus degree.

In this paper we have presented a adaptive module to guide consensus reaching processes that chooses preferences to change in each consensus round depending on the agreement that there exist at each moment. In such a way, we get to reduce the number of changes to suggest experts in each round and to increase the convergence of the consensus processes.

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