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Dealing With Ignorance Problems in Decision Making Under Fuzzy Preference Relations

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Abstract

Multiperson decision making problems involve using the preferences of some experts about a set of alternatives in order to find the best of those alternatives. However, sometimes experts cannot give all the information that they are required. Particularly, when dealing with fuzzy preference relations they can avoid giving some of the preference values of the relation. In previous works we developed a procedure able to estimate the missing values in the experts' fuzzy preference relations and we gave some basic approaches that would allow to solve *total ignorance* situations, that is, situations where an expert does not provide any information on at least one alternative (which could not be completed by the only application of the procedure). However, those approaches did not take into account any available external information in the problem. In this paper, we present some more advanced strategies which take advantage of other possible available sources of information as proximity among alternatives, proximity among the different experts in the problem and consensus information.

Keywords: Ignorance, Incomplete Information, Consensus, Multiperson Decision Making, Fuzzy Preference Relations.

1 Introduction

Multiperson decision-making (MPDM) consists of multiple individuals (usually experts) $E = \{e_1, ..., e_m\}$ which interact to reach a decision, that is, to choose the *best* alternative(s) from a feasible set of solution alternatives $X = \{x_1, ..., x_n\}$, $(n \geq 2)$ for the problem to be solved. Each expert may have unique motivations or goals and may approach the decision process from a different angle, but have a common interest in reaching eventual agreement on selecting the final solution(s) to the problem [5, 15]. Fuzzy preference relations are a preference representation format that has been widely used to express expert preferences over the set of possible solutions [3, 6, 7, 10, 18, 19].

It is a rather common situation in multiperson decision making when experts are not completely able to provide all the information that they are required [4, 12, 13, 14, 20]. For example, an expert might not possess a precise or sufficient level of knowledge of part of the problem or might be unable to discriminate the degree to which some options are better than others. In such cases, an expert would not be able to efficiently express any kind of preference degree between two or more of the available options, an therefore the fuzzy preference relation provided is *incomplete* [4, 20]. As usual decision models are not prepared to handle incomplete information situations (they usually require *complete* fuzzy preference relations as inputs) it is important to provide the experts with appropriate tools that allow them to overcome this lack of knowledge in their opinions.

Two different kinds of incomplete information in a MPDM problem can be identified:

- *Partial incomplete information.* In this case at least one expert does not provide all possible preference degrees over the set of alternatives, but provides information on his/her preferences in which every alternative is at least compared once against one of the rest of alternatives.
- *Total incomplete information.* In this case at least one expert does not provide all possible preference degrees over the set of alternatives, and provides information on his/her preferences in which at least one alternative is not compared against

any one of the rest of alternatives. We call this an *ignorance situation*.

The resolution of MPDM problems that present partial incomplete information has received some attention in the literature [1, 4, 9, 20]. However, the resolution of total incomplete information situations has yet received small attention. In [2] we pointed out four basic approaches to solve this kind of incomplete information situations. Nevertheless, those approaches were ad-hoc and consistency based strategies and thus, they did not make use of any external information that can be present in the problem.

In this paper we introduce some additional strategies that allow to solve total incomplete information situations in multiperson decision making which make use of information from different sources as information about the proximity of the alternatives, information about the proximity of the experts and consensus information in order to improve the results of the existent strategies. The use of these external sources of information can lead to the obtention of better quality solutions than the previously mentioned ad-hoc and consistency based strategies.

To do so, the rest of the paper is set out as follows: In *section 2* we present our preliminaries. *Section 3* presents three new strategies to solve the ignorance problem in MPDM which make use of one external information source (proximity of the alternatives, proximity of the experts or consensus among experts). In *section 4* we present an hybrid approach that is able to solve the ignorance problem using two or three of the possible external sources of information. Finally in *section 5* we point out some conclusions and future works.

2 Preliminaries

Fuzzy preference relations are commonly used to represent decision makers' preferences over the set of possible alternative solutions $X = \{x_1, ..., x_n\}$, $(n \geq 2)$ [3, 6, 7, 10, 11, 16, 18, 19].

Definition 1. A Fuzzy Preference Relation (FPR) P on a set of alternatives X is a fuzzy set on the product set $X \times X$, i.e., it is characterized by a membership function $\mu_P: X \times X \longrightarrow [0, 1]$.

When cardinality of X is small, the preference relation may be conveniently represented by the $n \times n$ matrix $P = (p_{ik})$, being $p_{ik} = \mu_P(x_i, x_k)$ $(\forall i, k \in \{1, \ldots, n\})$ interpreted as the preference degree or intensity of the alternative x_i over x_k: $p_{ik} = 1/2$ indicates indifference between x_i and x_k $(x_i \sim x_k)$, $p_{ik} = 1$ indicates that x_i is absolutely preferred to x_k, and $p_{ik} > 1/2$ indicates that x_i is preferred to x_k $(x_i \succ x_k)$. Based on this interpretation we have that $p_{ii} = 1/2$ $\forall i \in \{1, \ldots, n\}$ $(x_i \sim x_i)$.

Since each expert is characterized by his/her own personal background and experience of the problem to be solved, experts' opinions may differ substantially (there are plenty of educational and cultural factors that influence an expert's preferences). This diversity of experts could lead to situations where some of them would not be able to efficiently express any kind of preference degree between two or more of the available options. Indeed, this may be due to an expert not possessing a precise or sufficient level of knowledge of part of the problem, or because that expert is unable to discriminate the degree to which some options are better than others. We must note that an expert which is not able to provide a particular preference value p_{ik} does not necessarily imply that he/she is indifferent between both x_i and x_k alternatives, that is, we cannot directly suppose that $p_{ik} = 0.5$.

2.1 Incomplete Fuzzy Preference Relations

Usually, we assume that experts are always able to provide all the preferences required, that is, to provide all p_{ik} values. However, this may not always be the case, and experts end providing *incomplete fuzzy preference relations* [1, 20]. In the following definitions we express the concept of an incomplete fuzzy preference relation:

Definition 2. A function $f: X \longrightarrow Y$ is *partial* when not every element in the set X necessarily maps onto an element in the set Y. When every element from the set X maps onto one element of the set Y then we have a *total* function.

Definition 3. [1] An *Incomplete Fuzzy Preference Relation* P on a set of alternatives X is a fuzzy set on the product set $X \times X$ that is characterized by a *partial* membership function.

When a particular preference value p_{ik} is not given by an expert we will note $p_{ik} = x$ and we will call it a *missing value*.

From a particular incomplete fuzzy preference relation P^h we define the following sets [1]:

$$A = \{(i, j) \mid i, j \in \{1, \ldots, n\} \wedge i \neq j\}$$

$$MV^h = \{(i, j) \in A \mid p_{ij}^h = x\}$$

$$EV^h = A \setminus MV^h$$

$$EV_i^h = \{(a, b) \mid (a, b) \in EV^h \wedge (a = i \vee b = i)\}$$

where MV^h is the set of pairs of alternatives for which the preference degree of the first alternative over the second one is not given by expert e_h, that is, the set of *missing values* of the expert e_h, EV^h is the set of pairs of alternatives for which the expert e_h provides preference values (we call it the *expert values* for e_h) and EV_i^h is the set of preferences about pairs of alternatives given by e_h involving x_i.

An ignorance situation in MPDM problems is defined as follows:

Definition 4. Let $E = \{e_1, ..., e_m\}$ be a group of experts which have expressed their preferences on a set of alternatives $X = \{x_1, ..., x_n\}$ by means of a set of incomplete fuzzy preference relations $\{P^1, ..., P^m\}$. We define an ignorance situation in MPDM when at least one of the experts $e_h \in E$ does not provide any preference value involving a particular alternative $x_i \in X$, being x_i the unknown or ignored alternative for e_h, that is, $\exists i, h \mid EV_i^h = \emptyset$.

We must note that in [1, 9] we presented an estimation procedure able to estimate all missing values in an incomplete FPR except in ignorance situations, where the values that involve the ignored alternative could not be estimated. Thus, in the following we suppose that all the missing values in the FPR are the ones involving the unknown alternative (if not, we could use the procedure to estimate them).

3 Criteria Guided Strategies to Solve Ignorance Situations

In this section we present three different strategies to solve ignorance situations in MPDM which are based on the exploitation of external to the experts information. We will also provide some examples of application of every strategy. The first strategy is based on the proximity of the alternatives, and the second and third ones are based on *social properties* that can be obtained from the problem (proximity of the experts and the available consensus information).

3.1 Strategy 1: Estimate Ignored Information Considering the Proximity of the Alternatives

In some decision problems there exists information which relates the different alternatives among them. For example, for a particular problem, some of the alternatives could be similar. If this is the case, the preference values from an unknown alternative may be computed as some small random changes from the values provided for the similar alternative:

Estimation Procedure 1: If an incomplete fuzzy preference relation P^h has an unknown alternative x_i, and we know that alternative x_i is similar to alternative x_j (that is, they share several characteristics), this strategy will compute every missing value as:

$$\begin{array}{c} p_{ik}^h = rand(p_{jk}^h - \delta, p_{jk}^h + \delta) \\ p_{ki}^h = rand(p_{kj}^h - \delta, p_{kj}^h + \delta) \\ \forall k \in \{1, ..., n\}, k \neq i \neq j, \\ p_{ij}^h = rand(0.5 - \delta, 0.5 + \delta) \\ p_{ji}^h = rand(0.5 - \delta, 0.5 + \delta) \end{array}$$

where δ is a small factor (for example 0.1) that determines the magnitude on the change from the preference values of the similar alternative. This factor must be chosen prior to the beginning of the decision process (for example, the moderator can set this factor when defining the alternatives in the problem).

We must note that this kind of information (about the proximity of the alternatives) might not be present for every MPDM problem. Additionally, this kind of information cannot be obtained from the preferences provided by the rest of experts involved in the decision process. That is, if many experts choose very similar preference values for alternatives x_i and x_j, they cannot be considered as if they were similar options, because it would just mean that both options are more or less equally preferred, and thus, this strategy could not be applied on the unknown alternative.

Example 1: We have to solve a MPDM problem to find the best of 4 different alternatives: $X = \{x_1, x_2, x_3, x_4\}$. An expert e_1 gives the following incomplete fuzzy preference relation

$$P^1 = \begin{pmatrix} - & 0.7 & x & 0.68 \\ 0.4 & - & x & 0.7 \\ x & x & - & x \\ 0.6 & 0.75 & x & - \end{pmatrix},$$

If we know that alternative x_3 is similar to x_2 and we assume that $\delta = 0.1$ we can estimate the unknown values following the *estimation procedure 1*. For example: $p_{13} = rand(p_{12} - 0.1, p_{12} + 0.1) = rand(0.6, 0.8)$. A possible result of the application of the procedure is:

$$P^1 = \begin{pmatrix} - & 0.7 & \mathbf{0.76} & 0.68 \\ 0.4 & - & \mathbf{0.52} & 0.7 \\ \mathbf{0.41} & \mathbf{0.49} & - & \mathbf{0.63} \\ 0.6 & 0.75 & \mathbf{0.71} & - \end{pmatrix}$$

3.2 Strategy 2: Estimate Ignored Information Considering the Proximity of the Experts

This approach studies the similarities between experts to find which experts are similar to the expert which has not provided preference values for an unknown alternative. The preference values about the unknown alternative provided by the most similar experts are then used to estimate the ignored values:

Estimation Procedure 2: If an incomplete fuzzy preference relation P^h given by an expert e_h has an unknown alternative x_i, we apply the following scheme:

1. For every expert $e_v \in E$, $e_v \neq e_h$ {
2. Compute $d_v = dist(e_v, e_h)$
3. }
4. $NE = \{e_v \mid d_v < \gamma\}$
5. if $\#NE < 2$ {
6. NE = the 2 nearer experts
7. }
8. $p^h_{ik} = \phi^{v \in NE}\ p^v_{ik}$; $p^h_{ki} = \phi^{v \in NE}\ p^v_{ki}$

where $dist(e_a, e_b)$ computes a distance function between the two experts e_a and e_b, γ is a distance threshold to use the preferences from experts which are near to e_h and ϕ^{NE} is an aggregation operator that is used to aggregate different expert preference values. For simplicity reasons we propose the arithmetic mean as aggregation operator. Note that we do not provide a particular distance function as there are plenty that can be suitable to a particular problem.

Example 2: Lets suppose that expert e_1 provides the incomplete preference relation of the previous example (P^1). Additionally, experts e_2, e_3 and e_4 give the following preference relations:

$$P^2 = \begin{pmatrix} - & 0.6 & 0.4 & 0.7 \\ 0.4 & - & 0.7 & 0.4 \\ 0.6 & 0.35 & - & 0.6 \\ 0.3 & 0.7 & 0.4 & - \end{pmatrix}$$

$$P^3 = \begin{pmatrix} - & 0.3 & 0.6 & 0.25 \\ 0.7 & - & 0.55 & 0.5 \\ 0.4 & 0.45 & - & 0.7 \\ 0.8 & 0.5 & 0.3 & - \end{pmatrix}$$

$$P^4 = \begin{pmatrix} - & 0.6 & 0.5 & 0.7 \\ 0.4 & - & 0.65 & 0.75 \\ 0.5 & 0.35 & - & 0.7 \\ 0.3 & 0.25 & 0.3 & - \end{pmatrix}$$

We compute a distance between the experts, for example, as a mean of the error between the preference values given by each expert:

$$d_2 = dist(e_2, e_1) = 0.13 \ ; \ d_3 = dist(e_3, e_1) = 0.3$$

$$d_4 = dist(e_4, e_1) = 0.16$$

If we set the $\gamma = 0.15$, then $NE = \{e_2, e_4\}$ and we compute the ignored preference values as the arithmetic mean between the preference values of experts e_2 and e_4:

$$P^1 = \begin{pmatrix} - & 0.7 & \mathbf{0.45} & 0.68 \\ 0.4 & - & \mathbf{0.67} & 0.7 \\ \mathbf{0.55} & \mathbf{0.35} & - & \mathbf{0.65} \\ 0.6 & 0.75 & \mathbf{0.35} & - \end{pmatrix}$$

3.3 Strategy 3: Estimate Ignored Information Considering the Consensus Among Experts

If the resolution process for the MPDM problem involves obtaining a global opinion of consensus (consensus preference relation) [8, 16, 17, 19] (by means of an aggregation function over the different preference relations, for example) and it can be applied even if there exist missing values (aggregating only the given preference values, for example), its preference values about the unknown alternative can be used to complete the ignored preference values:

Estimation Procedure 3: If an incomplete fuzzy preference relation P^h has an unknown alternative x_i, and we have a global preference relation P^c which represents the current global opinion (solution of consensus) of all the experts on the problem, we can complete every missing value as:

$$p^h_{ik} = p^c_{ik} \ ; \ p^h_{ki} = p^c_{ki} \ \ \forall k \in \{1, ..., n\}, k \neq i.$$

Example 3: Lets suppose that expert e_1 provides the incomplete preference relation of the previous examples (P^1). Additionally, we know that the global (consensued) preference relation P^c is as follows:

$$P^c = \begin{pmatrix} - & 0.43 & 0.57 & 0.42 \\ 0.5 & - & 0.61 & 0.55 \\ 0.38 & 0.5 & - & 0.44 \\ 0.67 & 0.5 & 0.33 & - \end{pmatrix}$$

Then we can complete P^1 taking the unknown preference values from P^c:

$$P^1 = \begin{pmatrix} - & 0.7 & \mathbf{0.57} & 0.68 \\ 0.4 & - & \mathbf{0.61} & 0.7 \\ \mathbf{0.38} & \mathbf{0.5} & - & \mathbf{0.44} \\ 0.6 & 0.75 & \mathbf{0.33} & - \end{pmatrix}$$

4 Hybrid Strategy

The presented strategies solve the ignorance problem by taking into account only one external source of information (promixity of the alternatives, proximity of the experts or consensus among experts). However, we think that to obtain better solutions it would be of great interest to be able to integrate all the available external sources of information. For example, if for a particular MPDM problem there is information about proximity of the alternatives and we can compute the proximity of the expert with an unknown alternative to the other experts it would be interesting to solve the ignorance problem taking into account both sources of information.

To do so, we provide the following generic procedure which is able to solve the ignorance problem taking into account the three possible external sources of information. It makes use of the previously presented strategies. We suppose that expert e_h has an unknown alternative x_i in his incomplete fuzzy preference relation P^h:

1. *StrategiesCount* = 0
2. if information about *proximity of alternatives* {
3. Compute $(p^h_{ik})^1$ and $(p^h_{ki})^1$ with *strategy 1*
4. *StrategiesCount* + +
5. } else {
6. $(p^h_{ik})^1 = (p^h_{ki})^1 = 0$
7. }
8. Compute $(p^h_{ik})^2$ and $(p^h_{ki})^2$ with *strategy 2*
9. *StrategiesCount* + +
10. if information about *consensus* {
11. Compute $(p^h_{ik})^3$ and $(p^h_{ki})^3$ with *strategy 3*
12. *StrategiesCount* + +
13. } else {
14. $(p^h_{ik})^3 = (p^h_{ki})^3 = 0$
15. }
16. Compute $p^h_{ik} = \frac{(p^h_{ik})^1 + (p^h_{ik})^2 + (p^h_{ik})^3}{StrategiesCount}$
17. Compute $p^h_{ki} = \frac{(p^h_{ki})^1 + (p^h_{ki})^2 + (p^h_{ki})^3}{StrategiesCount}$

We must note that *strategy 2* can always be applied (it is possible to measure the distance from e_h to the rest of the experts and it uses at least the information of the two nearest experts to compute the ignored values) whilst *strategy 1* and *strategy 3* can only be applied if the appropiate source of information is available, and thus, the *StrategiesCount* variable is needed to control the final computation of the ignored values.

Example 4: Lets suppose that expert e_1 provides the incomplete preference relation of the previous examples (P^1), that experts e_2, e_3 and e_4 provide the preference relations presented in *example 2*, that there is information about consensus (the P^c preference relation of *example 3*), and additionally we have a piece of information that says that x_2 is similar to x_3. Then we can use all of this information to compute the ignored preference values (as the arithmetic mean of the values obtained by the application of the three strategies):

$$P^1 = \begin{pmatrix} - & 0.7 & \mathbf{0.59} & 0.68 \\ 0.4 & - & \mathbf{0.6} & 0.7 \\ \mathbf{0.45} & 0.45 & - & \mathbf{0.57} \\ 0.6 & 0.75 & \mathbf{0.46} & - \end{pmatrix}$$

5 Conclusions and Future Works

In this paper we have presented some strategies to solve ignorance situations in MPDM, that is, situations where at least one expert involved in the resolution process does not provide any information on at least one alternative. The presented approaches differ from some previous efforts to solve this situations because they make use of external to the experts information (the previous approaches used ad-hoc and consistency based methodologies to solve the problem). Some of the external information that is used in the presented strategies comes from some social properties present in the resolution process for the MPDM problem, such as the proximity of the experts (the proximity of their opinions) and the available consensus information (information about the current consensus solution). We also provide a hybrid strategy that allows to exploit all available external information.

In future works we will study how to hybridize the presented strategies with consistency strategies, that is, we will define strategies that will solve the ignorance problem taking into account both external information (consensus or proximity of experts) with internal information (consistency of the experts).

Additionally, the strategies will be improved by integrating them in an on-line decision process which will allow to incorporate user satisfaction on the ignorance problem (the experts will be able to accept or refuse the estimations obtained by the different strategies according to their point of view).

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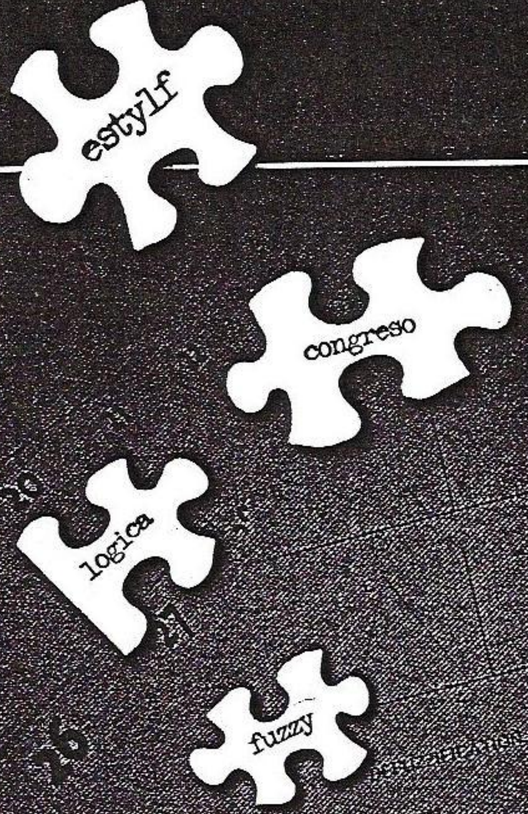

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Desde estas líneas queremos agradecer a todos los que han contribuido a la elaboración de estas actas, tanto en su aspecto visual como en sus contenidos. De igual forma agradecemos la colaboración de las instituciones que han participado y con su apoyo han permitido la celebración de este congreso científico bianual.

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Toma de Decisiones: Modelado y Agregación de Preferencias Difusas

Organizadores: Enrique Herrera-Viedma y Francisco Herrera Triguero (*Red Temática Nacional sobre Procesos de Toma de Decisiones: Modelado y Agregación de Preferencias*).

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Y para que así conste y tenga los efectos oportunos, se extiende el presente certificado a 17 de Julio de 2006.

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