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A Web Consensus Support System to Deal with GDM Problems under Incomplete Fuzzy Preference Relations

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Abstract

Reaching a good consensus level among experts is a critical activity to solve Group Decision Making problems. Usually, it is the moderator task to assure that the consensus process is carried out properly and, if it is possible, to offer recommendations to the experts in order that they change their opinions and narrow their differences. In this paper we present a Web consensus support system which is able to help, or even replace the moderator role in a consensus process based on incomplete fuzzy preference relations. This system is based in both consistency and consensus measures and it has been designed to provide advice to the experts to increase the consensus level in the group while maintaining the individual consistency expressed by each expert and helping the experts to reduce the incompleteness of their fuzzy preference relations. The system provides a Web interface which allows to carry out consensus processes where the experts do not have the possibility to physically meet together.

Keywords: Consensus, Group Decision Making, Incomplete Fuzzy Preference Relations, Web.

1 Introduction

In Group Decision Making (GDM) problems there are usually two processes to carry out before obtaining a final solution [6, 7, 12, 15]: *the consensus process* and *the selection process*. The former refers to how to obtain the maximum degree of consensus or agreement between the set of experts on the solution set of alternatives. The latter [9, 19] consists in how to obtain the solution set of alternatives from the opinions on the alternatives expressed by the experts. Normally, the consensus process is guided by the figure of a moderator [7, 8, 15, 14, 5] and it is carried out before the selection process. Clearly, the consensus process is an important step in solving group decision making problems because it aids to obtain solutions with higher levels of consensus among experts (which is usually desirable).

There are several aspects that have to be specified prior to the solving of a group decision making problem. For example, we have to define the representation format in which experts will express their preferences about the possible alternatives in the problem. One of the most used representation formats in decision making theory are fuzzy preference relations [3, 13, 16]. This representation format presents a high expressivity and some interesting properties that allow to operate with them easily.

Despite of the good qualities of fuzzy preference relations, in real world GDM problems it is common to find incomplete information situations [4, 10, 11, 17, 18, 21], that is, situations in which experts are not able to provide all the preference values that are required, and then we have to deal with *incomplete fuzzy preference relations* [10, 11].

The aim of this paper is to present a new Web based consensus support system [2, 22] to deal with GDM problems under incomplete fuzzy preference relations. This system is designed to help the moderator to carry out his/her duties during the different steps of the consensus process, but the system could even replace most of the activities of the moderator once the initialization steps have been carried out. The activity of the consensus support system is based on both consensus and consistency measures which are interactively computed when the experts provide their preferences in form of incomplete fuzzy preference relations. With these measures the system is able to provide some advice to the experts (through the use of a feedback mechanism) on how to change their opinions to reach a good solution of consensus whilst they maintain a high degree of consistency in their individual preference relations, and thus, avoiding self-contradiction. The feedback is expressed as a set of rules for every expert. Additionally, the rules offered to each expert will help them on completing their preference values (when they provided incomplete information). The system has been implemented and the experts can use it via a Web interface which allows to carry out consensus processes in situations where the experts do not have the possibility to physically meet together (for example, when they are in different countries).

The rest of the paper is set out as follows: Section 2 presents the theoretical model for the Web consensus support system. Section 3 describes the details of the implementation of the consensus support system. Finally, Section 4 draws our conclusions and future improvements.

2 Theoretical Model for the Web Consensus Support System

In [10] we developed a theoretical consensus model which used some consistency and consensus measures to guide the consensus process in GDM under incomplete fuzzy preference relations. In this section we will briefly describe it to show the basis of the Web Consensus Support System that we present in this paper. To do so, in the following subsections we present the concept of incomplete fuzzy preference relations and the elements of theoretical consensus model.

2.1 Incomplete Fuzzy Preference Relations

Fuzzy preference relations are a very widely used representation format to represent preferences [13, 16, 20] because of their expressiveness and its properties that allow to operate with them easily.

Definition 1: A *fuzzy preference relation* P on a set of alternatives $X = \{x_1, \ldots, x_n\}$ is a fuzzy set on the product set $X \times X$, i.e., it is characterized by a membership function $\mu_P \colon X \times X \longrightarrow [0, 1]$.

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, $p_{ik} = 1$ indicates that x_i is absolutely preferred to x_k, and $p_{ik} > 1/2$ indicates that x_i is preferred to x_k.

We have previously mentioned that in many real world GDM problems the experts are often not able to provide all the preference values that are required, and then the it appears the concept of *incomplete fuzzy preference relation* [11]:

Definition 2: A function $f \colon X \longrightarrow Y$ 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: 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 func-

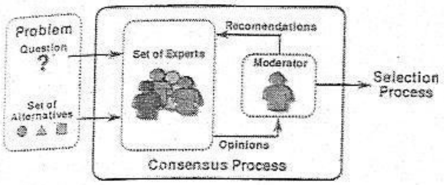

Figure 1: Consensus Process

tion.

2.2 The Consensus Model based on Consensus and Consistency Measures

A typical consensus process is depicted as in figure 1. In a GDM situation we assume that a problem and a set of feasible alternatives are presented to the experts. Those experts provide the moderator with their preferences about the alternatives. The moderator checks if the level of agreement is enough. If so, the consensus process would stop and the selection process would be carried out. If the agreement (or consensus) is not high enough, the moderator gives recommendations to the experts in order that they change their opinions to obtain a solution of consensus. Taking into account those recommendations the experts express (again) their preferences about the alternatives and a new round of the consensus process starts.

In this paper we follow a consensus model based on consensus and consistency measures that uses incomplete fuzzy preference relations to represent the experts' preferences. Its activity is similar to that shown in Figure 1, but it requires to define consistency measures, consensus measures, consistency and consensus control processes and feedback mechanisms, and to assume the presence of incomplete fuzzy preference relations.

2.2.1 Consistency Measures

In [11] we developed some consistency measures for incomplete fuzzy preference relations based on the *additive transitivity* [20]:

$$(p_{ij} - 0.5) + (p_{jk} - 0.5) = (p_{ik} - 0.5) \quad (1)$$

The consistency measures are computed as the error among the values provided by expert e_h (p^h_{ik}) and the values cp^h_{ik} computed by some expressions derived from the previous expression (you can check the details in [11]). Note that we compute consistency measures at three different levels: Level of pair of alternatives (cl^h_{ik}), level of alternatives (cl^h_i) and level of preference relation (cl^h).

2.2.2 Consensus Measures

In order to develop a theoretical consensus model for GDM problems, in [10] we defined two different kinds of consensus measures that are used to not only determine the current consensus state at a particular round of consensus but also to compute some values that will be used to provide the experts with some advice about how to change their preferences in order to reach a consensus solution for the problem. These measures are *consensus degrees* and *proximity measures*. The former measure the current level of consensus among experts and the latter measure how far is each expert from the consensus solution. Both kinds of measures are computed at the three previously commented levels:

- *Consensus degrees:* Consensus degree on pairs of alternatives (cop_{ik}), consensus degree on alternatives (ca_{ik}) and consensus degree on the relation (CR).

- *Proximity measures:* Proximity measure on pairs of alternatives (pp^h_{ik}), proximity measure on alternatives (pa^h_i) and proximity measure on the relation (pr^h).

2.2.3 Controlling the Consensus and Consistency State

Once the experts provide their preferences and we have computed the previously presented measures the system can check the current consensus and consistency state. To do so, it computes a combined measure called *consistency/consensus level (CCL)* which is used as a control parameter:

$$CCL = (1 - \delta) \cdot CL \; + \; \delta \cdot CR$$

If CCL satisfies a minimum satisfaction threshold value $\gamma \in [0, 1]$, then the consensus reaching process finishes and the selection process can be applied. Otherwise, the feedback mechanism is activated. Additionally, a maximum number of consensus rounds parameter Max_{rounds} is used. If the current number of rounds is equal than Max_{rounds} then the consensus process ends (independently of the current CCL value) to avoid stagnation.

2.2.4 The Feedback Mechanism

The feedback mechanism generates advice to the experts according to the consistency and consensus criteria. This activity is carried out in two steps: *Identification of the preference values* that should be changed and *Generation of advice.*

To identify the preference values that should be changed we use a three step identification process which uses the consistency and consensus measures to identify the experts, alternatives and finally the particular preference values which contribute less to the consistency and consensus state.

Once that those preference values have been identified we generate recommendations to the experts about how to change their preference values in form of easy rules as:

Expert e_h should change his p_{ik}^h preference to a value near rp_{ik}^h.

where rp_{ik}^h has been computed taking into account his own preferences, the current consensus values and the consistency and consensus measures. For more details about the control of the consensus/consistency state and the feedback mechanism, check [10].

3 Implementation of the Web Based Consensus Support System

Nowadays Web-based applications are increasingly being used for GDM and Decision Support environments [2, 22] because they offer many advantages as the possibility of accessing them from all over the world and thus, the possibility of carrying out decision making processes where experts cannot meet physically together. We present a Web Consensus Support System that is programmed using a LAMP stack (GNU/Linux operating system, Apache web server, MySQL database server and PHP programming language). It also makes use of Java technologies for the most complex interface tasks. In this section we describe its main modules: *main module, moderator's module, expert's module* and *computing module* and how the users of the system (moderator and experts) are supposed to interact with them.

3.1 Main Module

The main module of the system is encharged of giving access to the other modules and acts as a starting point to begin using the system. It controls the access of the users of the system assuring that non-moderator users cannot access to the moderator module and that only the registered experts can access to the expert's module for each problem on the system. To do so, this module presents a login screen where the user is prompted for his e-mail address, password and problem. Once the user introduces his login information the system checks if the information is correct and redirects the user to his corresponding module (moderator's or expert's module). Usual security measures are taken into account (for example, notice the moderator via email of several incorrect login attemps from a particular computer) to avoid unauthorized login into the system.

3.2 Moderator's Module

Once a moderator has logged into the system he is presented with a screen with several possible actions: *Change his password, Create a GDM problem, Show the current status of a GDM process* and *Log out.*

To create a new GDM problem involves a three step procedure:

1. *Basic definition of the problem:* problem name, description, maximum number of consensus rounds, several control parameters

(stop conditions, consensus/consistency balance), number of experts involved and number of alternatives in the problem.

2. *Definition of alternatives:* Alternative names, description and an optional image.

3. *Registration of the experts:* Name, e-mail and initial password for each expert.

Once the information for the problem if provided the moderator finishes the creation process by clicking on a button. Then the system automatically e-mails the registered experts providing them with information about the problem, their login details for the system and basic instructions about the use of the web-system.

The moderator also can check the current status of a problem, that is, all the preferences that were given by the experts in every consensus round, the measures that have been computed, the recommendations given to the experts and the final solution of the problem when it is finished.

3.3 Expert's Module

The main goal of the expert's module is to help experts to provide their preferences to the system assuring that those preferences are as consistent as possible and also to show the feedback recommendations that will be generated by the computation module after every round of the consensus process. Once the expert has logged into the system he is presented with the information about the problem in which he is participating. Additionally, if there exist some recommendations for him about how to change his preferences (given in the previous consensus round), these recommendations are shown to him among with the consensus and consistency measures computed for this consensus round.

To help experts to express their preferences a Java applet which was developed in [1] is presented. It is designed to help them to provide consistent (and complete) fuzzy preference relations by informing them in real time about the possible inconsistencies that they may have introduced. Additionally it provides some hints about the particular preference values that they should provide in order to express consistent fuzzy preference relations. In figure 2 we show a snapshot of the expert's module where some recommendations are given and where part of the Java applet is shown.

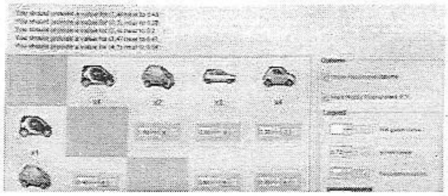

Figure 2: Expert's module snapshot

3.4 Computing Module

This module computes all the consistency and consensus measures and also generates the recommendations which will be presented to the experts when every consensus round for a problem is finished (that is, when the last expert provides his preferences in a consensus round). This module is also encharged of checking if the current consistency and consensus state reaches a certain desired level and if so, to begin the selection process in order to obtain the final solution of the problem. All the computations and recommendations are stored among with the preferences expressed by the experts in a database. When all the computation steps finish, this module will inform the experts and the moderator about the progress of the consensus process. To do so it sends e-mails to the moderator and the experts detailing the results of the computations and asking the experts to continue with the next consensus round if neccessary.

4 Conclusions and Future

We have presented a Web consensus support system to deal with GDM problems. It is designed to facilitate experts to express their preferences about the alternatives in the problem while maintaining their consistency and to provide some easy to understand recommendations (replacing the role of the moderator) which will help them to converge into a solution for the problem achieving a high level of consensus.

In future works we will improve the system by incorporating more information tools for the experts and producing some interface improvements that will allow to access it from almost any mobile device.

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