Modelling Group Decision Making Problems in Changeable Conditions

Ignacio J. Pérez[1], Sergio Alonso[2],
Francisco J. Cabrerizo[3], and Enrique Herrera-Viedma[1]

[1] Dept. of Computer Science and Artificial Intelligence, University of Granada, Spain
ijperez@decsai.ugr.es, viedma@decsai.ugr.es
[2] Dept. of Software Engineering, University of Granada, Spain
zerjioi@ugr.es,
[3] Dept. of Software Engineering and Computer Systems, Distance Learning University of Spain (UNED), Madrid, Spain
cabrerizo@issi.uned.es

Abstract. The aim of this paper is to present a new group decision making model with two important characteristics: i) we apply mobile technologies in the decision process and ii) the set of alternatives is not constant through time. We implement a prototype of a mobile decision support system based on changeable sets of alternatives. Using their mobile devices (as mobile phones or PDAs), experts can provide/receive information in anywhere and anytime. The prototype also incorporates a new system to manage the alternatives and thus, to give more realism to decision processes allowing to manage changeable set of alternatives, focussing the discussion in a subset of them that changes in each stage of the process.

Keywords: Group decision making, mobile internet, dynamic environment.

1 Introduction

Group Decision Making (GDM) arises from many real world situations [1, 2]. As a result, the study of decision making is necessary and important not only in Decision Theory but also in areas such as Management Science, Operations Research, Politics, Social Psychology, and so on. In such problems, there are a set of alternatives to solve a problem and a group of experts trying to achieve a common solution. To do this, experts have to express their preferences by means of a set of evaluations over the set of alternatives.

Nowadays, we are realizing many significant advances in the way human interact with technology. The spread of e-services and wireless or mobile devices has increased accessibility to data and, in turn, influenced the way in which users make decisions while they are on the move. Users can make real-time decisions based on the most up-to-date data accessed via wireless devices, such as portable computers, mobile phones, and personal digital assistants (PDAs), which are usually carried all the time and allows to make decisions anytime and anywhere. Thus, the adoption of the latest mobil technologies extends opportunities and allows to carry out consensus processes where previously could not be correctly addressed. Such adoption is based on the assumption that if the communications are improved the decisions will be upgraded, because

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the discussion could be focussed on the problem with less time wasted on unimportant issues [3, 4].

Usually, resolution methods for GDM problems are static, that is, it is assumed that the number of alternatives and experts acting in the GDM problem remains fixed throughout the decision making process. However, in real decision situations we find dynamic GDM problems in which the number of alternatives and/or experts could vary during the decision making process. Sometimes, where the decision process is slow or it takes a long time, the set of feasible alternatives is dynamic because their availability or feasibility could change through the decision making time. For example, in e-commerce decision frameworks, where the alternatives are the items that could be bought, it is possible that the availability of some of these items changes while experts are discussing and making the decision, even, new good items might become available. In this paper, we assume GDM problems with changeable set of alternatives.

The aim of this paper is to present a prototype of Decision Support System (DSS) to deal automatically with dynamic GDM problems assuming different preference representations and based on mobile technologies. We present a tool to control the possible changes of alternatives that could appear through the decision making process. At every stage of the decision process, the users (i) will be informed with updated data about the current stage of the decision process, (ii) will receive recommendations to help them to change their preferences, and (iii) will be able to send their updated preferences at any moment, thus improving the user participation in the GDM process. . In order to build a flexible framework and give a high degree of freedom to represent the preferences, experts are allowed to provide their preferences in any of the following four ways: (i) as a preference ordering of the alternatives, (ii) as an utility function, (iii) as a fuzzy preference relation, or (iv) as a multiplicative preference relation.

To do so, the paper is set out as follows: Some considerations about GDM problems and mobile technologies are presented in Section 2. Section 3 deals with the prototype which implements such mobile DSS. Finally, in Section 4 we point out our conclusions.

2 Preliminaries

In this section we present the classical GDM model and the advantages of using mobile technology in GDM problems.

2.1 Group Decision Making Models

In a GDM problem we have a finite set of feasible alternatives, $X = \{x_1, x_2, \ldots, x_n\}$, $(n \geq 2)$, to be ranked from best to worst using the information given by a set of experts, $E = \{e_1, e_2, \ldots, e_m\},\ (m \geq 2)$.

Usual resolution methods for GDM problems include two different processes [5, 6] (see Figure 1):

1. *Consensus process:* Clearly, in any decision process, it is preferable that the experts reach a high degree of consensus on the solution set of alternatives. Thus, this process refers to how to obtain the maximum degree of consensus or agreement between the set of experts on the solution alternatives.

2. *Selection process:* This process consists in how to obtain the solution set of alternatives from the opinions on the alternatives given by the experts.

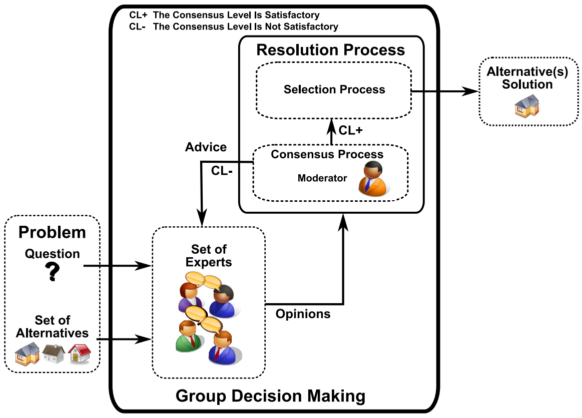

Fig. 1. Resolution process of a GDM

Usually, resolution methods for GDM problems are static, that is, it is assumed that the number of alternatives and experts acting in the GDM problem remains fixed throughout the decision making process. However, in real decision situations we find dynamic GDM problems in which the number of alternatives and/or experts could vary during the decision making process. In this paper, we assume GDM problems with changeable sets of alternatives.

On the other hand, as each expert, $e_k \in E$, has his own ideas, attitudes, motivations and personality, it is quite natural to think that different experts could express their preferences in a different way. This fact has led some authors [7, 8, 9, 10, 11, 12] to assume that experts' preferences over the set of alternatives may be represented in different ways. Amongst these, the most frequently used in decision making theory are:

- *Preference orderings of alternatives:* $O^k = \{o^k(1), ..., o^k(n)\}$, where $o^k(\cdot)$ is a permutation function over the index set, $\{1, ..., n\}$, for the expert, e_k, defining an ordered vector of alternatives, from best to worst.
- *Utility functions:* $U^k = \{u_1^k, ..., u_n^k\}$, $u_i^k \in [0, 1]$, where u_i^k represents the utility evaluation given by the expert e_k to x_i.
- *Fuzzy preference relations:* $P^k \subset X\text{x}X$, with a membership function, $\mu_{P^k} : X\text{x}X \rightarrow [0, 1]$, where $\mu_{P^k}(x_i, x_j) = p_{ij}^k$ denotes the preference degree of x_i over x_j.
- *Multiplicative preference relations:* $A^k \subset X\text{x}X$, where the intensity of preference, a_{ij}^k, is measured using a ratio scale, particularly the 1/9 to 9 scale;

2.2 Mobile Technologies Usage in GDM Problems

During the last decade, organizations have moved from face-to-face group environments to virtual group environments using communication technology. More and more workers use mobile devices to coordinate and share information with other people. The main objective is that the members of the group could work in an ideal way where they are, having all the necessary information to take the right decisions [3, 4, 13, 14].

To support the new generation of decision makers and to add real-time process in the GDM problem field, many authors have proposed to develop decision support systems based on mobile technologies [15, 16]. Similarly, we propose to incorporate mobile technologies in a DSS obtaining a Mobile DSS (MDSS). Using such a technology should enable a user to maximize the advantages and minimize the drawbacks of DSSs.

The need of a face-to-face meeting disappears with the use of this model, being the own computer system who acts as moderator. Experts can communicate with the system directly using their mobile device from any place in the world and at any time. Hereby, a continuous information flow among the system and each member of the group is produced, which can help to reach the consensus between the experts on a faster way and to obtain better decisions.

In addition, MDSS can help to reduce the time constraint in the decision process. Thus, the time saved by using the MDSS can be used to do an exhaustive analysis of the problem and obtain a better problem definition. This time also could be used to identify more feasible alternative solutions to the problem, and thus, the evaluation of a large set of alternatives would increase the possibility of finding a better solution. The MDSS helps to the resolution of GDM problems providing a propitious environment for the communication, increasing the satisfaction of the user and, in this way, improving the final decisions.

3 A Mobile DSS Based on Changeable Sets of Alternatives

In this section we describe the mobile DSS that incorporates a tool to manage GDM problems in which the set of alternatives could change throughout the decision process. It allows to develop GDM processes at anytime and anywhere, and simulate with more accuracy level the real processes of human decision making which are developed in dynamic environments as the Web, financial investment, health, etc. In what follows we explain the "client/server" architecture of the mobile DSS and the communication and work flow that summarizes the functions of the DSS.

3.1 Server Side

We assume that before to start the GDM process, the moderator selects the feasible set of experts and alternatives and establishes the remaining parameters of the problem. Thus, the structure of the proposed Mobile DSS server is composed of the following five processes: (i) uniformization process, (ii) selection process, (iii) consensus process, (iv) dynamic choice process of alternatives, and (v) feedback process (Figure 2).

Uniformization Process: To give a higher degree of freedom to the system, we assume that experts can present their preferences using any of the preference representations presented in section 2.1. Therefore, it is necessary to make the information uniform before applying the consensus and selection processes. As in [8] we propose to

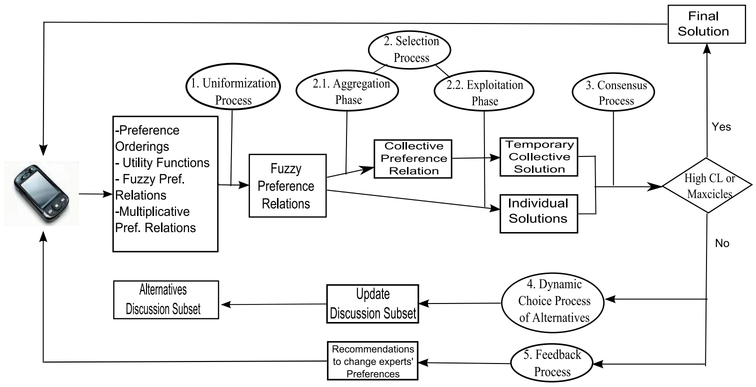

Fig. 2. Structure of the DSS server with multiple preference representation structures

use fuzzy preference relations as the base element to uniform experts' preferences and the following transformation functions are used [8]: $f^1\left(o_i^k, o_j^k\right) = \frac{1}{2}\left(1 + \frac{o_j^k - o_i^k}{n-1}\right)$, $f^2\left(u_i^k, u_j^k\right) = \frac{\left(u_i^k\right)^2}{\left(u_i^k\right)^2 + \left(u_j^k\right)^2}$, $f^3\left(a_{ij}^k\right) = \frac{1}{2}\left(1 + \log_9 a_{ij}^k\right)$.

Selection Process: Once the information is made uniform, we have a set of m individual fuzzy preference relations and then we apply a selection process which has two phases [2, 17]: (i) *aggregation* and (ii) *exploitation*.

– *Aggregation phase:*
  This phase defines a collective preference relation, $P^c = \left(p_{ij}^c\right)$, obtained by means of the aggregation of all individual fuzzy preference relations $\left\{P^1, P^2, \ldots, P^m\right\}$. It indicates the global preference between every pair of alternatives according to the majority of experts' opinions. For example, the aggregation could be carried out by means of an OWA operator [18, 19].
– *Exploitation phase:*
  This phase transforms the global information about the alternatives into a global ranking of them, from which the set of solution alternatives is obtained. The global ranking is obtained applying two choice degrees of alternatives to the collective fuzzy preference relation [20]: the *quantifier guided dominance degree* (QGDD) and the *quantifier guided non dominance degree* (QGNDD).
  Finally, the solution X_{sol} is obtained by applying these two choice degrees, and thus, selecting the alternatives with maximum choice degrees.

Consensus Process: In our mobile DSS, we use a consensus model for GDM problems with different preference representations as it was done in [21]. This model presents the following main characteristics:

– It is based on two soft consensus criteria: global consensus measure on the set of alternatives X, symbolized as C_X, and the proximity measures of each expert e_i on X, called P_X^i.

– Both consensus criteria are defined by comparing the individual solutions with the collective solution using as comparison criterion the positions of the alternatives in each solution.

Initially, in this consensus model we consider that in any nontrivial GDM problem the experts disagree in their opinions so that consensus has to be viewed as an iterated process. This means that agreement is obtained only after some rounds of consultation. In each round, the DSS calculates both the consensus and the proximity measures. The consensus measures evaluate the agreement existing among experts and the proximity measures are used in the feedback mechanism to support the group discussion phase of the consensus process.

Dynamic Choice Process of Alternatives: In real world we find many dynamic decision frameworks: health, financial investment, military operations, Web. In such cases, due to different factors the set of solution alternatives could vary throughout the decision process.

Classical GDM models are defined within static frameworks. In order to make the decision making process more realistic, we provide a new tool to deal with dynamic alternatives in decision making. In such a way, we can solve dynamic decision problems in which, at every stage of the process, the discussion could be centered on different alternatives.

To do so, we define a method which allows us to remove and insert new alternatives into the discussion process. Firstly, the system identifies those worst alternatives that might be removed and the new alternatives to include in the set. This new alternatives can be obtained from a set of new alternatives appeared at a time or from the supply set of alternatives that includes all the alternatives that we had at the beginning of the process but that were not included in the discussion subset because the limitation of this due to specific parameters of the problem. It is worth noting that we assume that alternatives are independent and the inclusion or elimination of one alternative can not change the ranking of other pairs of alternatives.

Thus, the method has two different phases: (1) Remove old bad alternatives and and (2) Insert new good alternatives.

1. The first phase manages situations in which some alternatives of the discussion subset are not available at the moment due to some dynamic external factors or because the experts have evaluated them poorly and they have a low dominance degree ($QGDD$). Therefore, the system checks the availability and the $QGDD$ of each alternative in the current discussion subset. If some alternative is not available or has a $QGDD$ lower than a threshold ($minQGDD$), the system looks for a new good alternative in the new alternatives subset. If this subset is empty, the system uses the supply subset of alternatives provided by the expert at the beginning of the decision process and that were not taken into account then because of the impossibility to compare all the alternatives at the same time. Then, the system asks for the experts' opinions about the replacement and acts according to them (see Figure 3).
2. The second case manages the opposite situation, that is, when some new alternatives have emerged. Basically, the system checks if some new good alternatives

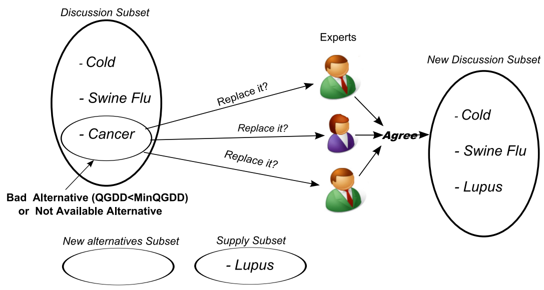

Fig. 3. Dynamic choice process of alternatives: Case 1

have appeared in the new alternatives subset due to some dynamic external factors. If this is the case, the system has to identify the worst alternatives of the current discussion subset. To do this, the system uses the dominance degree $QGDD$ of all alternatives again to choose the worst alternatives. Then, the system asks for the experts' opinions about the replacement and acts according to them (see Figure 4).

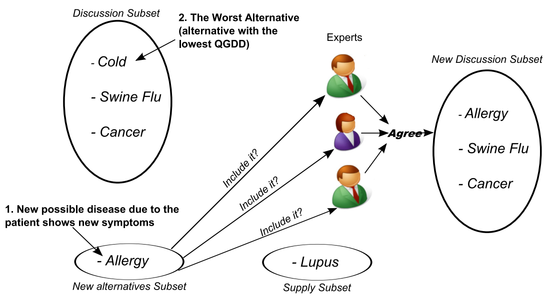

Fig. 4. Dynamic choice process of alternatives: Case 2

Feedback Process: To guide the change of the experts' opinions, the DSS simulates a group discussion session in which a feedback mechanism is applied to quickly obtain a high level of consensus. This mechanism is able to substitute the moderator's actions in the consensus reaching process. The main problem is how to find a way of making individual positions converge and, therefore, how to support the experts in obtaining and agreeing with a particular solution.

When the consensus measure C_X has not reached the required consensus level (CL) and the number of rounds has not reached a maximum number of iterations (MAXCYCLE), defined prior to the beginning of the decision process, the experts' opinions must be modified. As aforementioned, we are using the proximity measures to build a feedback mechanism so that experts can change their opinions and narrow their positions.

3.2 Client Side

For the implementation of the DSS we have chosen a thin client model. This model depends primarily on the central server for the processing activities. This prototype is designed to operate on mobile devices with Internet connection.

The client software has to show to the experts the next eight interfaces:

- Connection: The device must be connected to the network to send/receive information to the server.
- Authentication: The device will ask for a user and password data to access the system.
- Problem description: When a decision process is started, the device shows to the experts a brief description of the problem and the discussion subset of alternatives (see Figure 5 a).
- Selection of preference representations (see Figure 5 b).

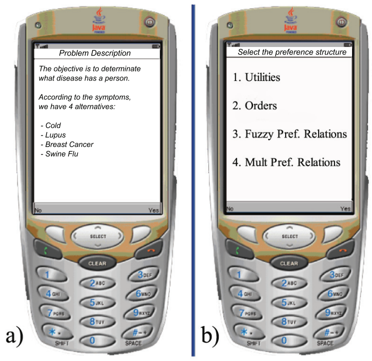

Fig. 5. Problem description and selection of preference representations

- Insertion of preferences: The device will have four different interfaces, one for each different format of preference representation (see Figure 6).
- Change of alternatives: When a bad or not available alternative deserves to be removed from the discussion subset, or a new alternative deserves be inserted in the discussion subset, using the new management process of alternatives, the experts can assess if they want to update the discussion subset by changing these alternatives (see Figure 7).
- Feedback: When opinions should be modified, the device shows to the experts the recommendations and lets them send their new preferences (see Figure 8 a).
- Output: At the end of the decision process, the device will show to the experts the set of solution alternatives as an ordered set of alternatives marking the most relevant ones (see Figure 8 b). The system shows an additional scoring (QGDD) of each alternative when the problem needs more than one of them to be solved. Moreover, if the minimum consensus level is not reached and temporary solution becomes final solution because the maximum number of feedback cycles has been reached, the system notes this situation and it shows the current consensus level on the screen.

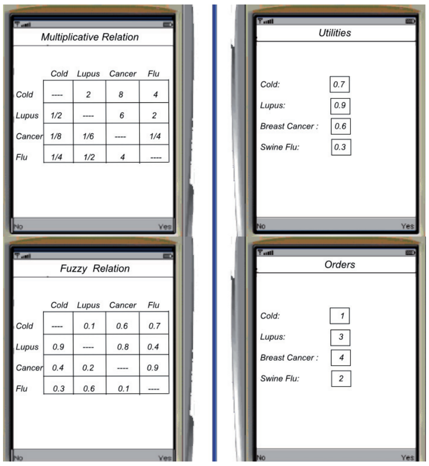

Fig. 6. Insertion of preferences

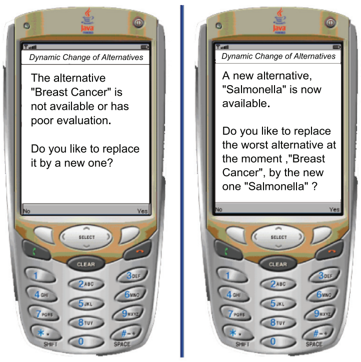

Fig. 7. Change of alternatives question

On the technical side of the development of the client part of the DSS, it is worth noting that the client application complies with the MIDP 2.0 specifications [22], and that the J2ME Wireless Toolkit 2.2 [23] provided by SUN was used in the development phase. This wireless toolkit is a set of tools that provide J2ME developers with some emulation environments, documentation, and examples to develop MIDP-compliant applications. The application was later tested with a toy example using a JAVA-enabled mobile phone on a GSM network using a GPRS-enabled SIM card. If the discussion subset of alternatives is large and can not be displayed on the screen, Java interface provides scrolling tools that allows displaying bigger interfaces on small screens. The MIDP application is packaged inside a JAVA archive (JAR) file, which contains the applications classes and resource files. This JAR file is the one that actually is downloaded to the physical device (mobile phone) along with the JAVA application descriptor file when an expert wants to use the MDSS.

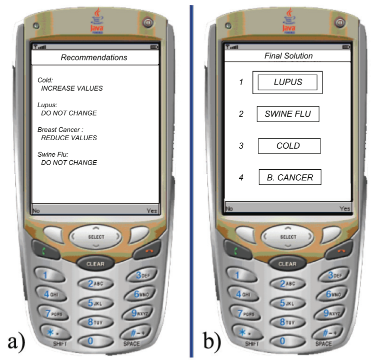

Fig. 8. Recommendations and Final Solution

3.3 Communication and Work Flow

The DSS has to carry out the following functions, also represented in figure 9. In the diagram we can see all the functions of the system, the form in which they are connected together with the database, and the order in which each of them is executed.

0. Database initialization
1. Verify the user messages and store the main information
2. Make the experts' preferences uniform
3. Computation of the set of solution alternatives
4. Computation of the consensus measures
5. Control the consensus state
6. Control the change of alternatives

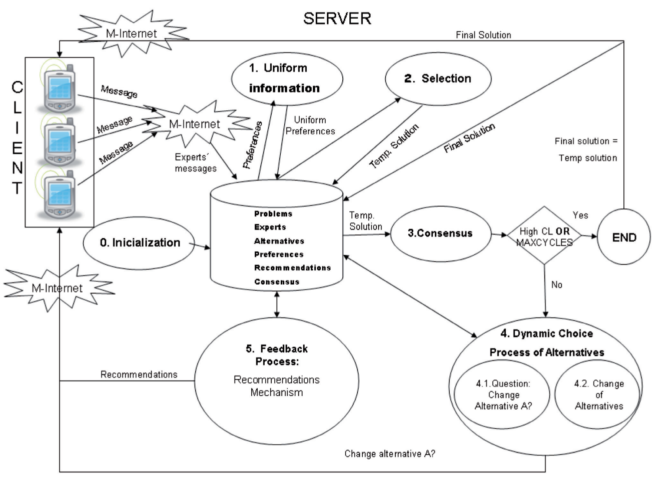

Fig. 9. Functions Scheme of the System

7. Generate the recommendations
8. Go to step 1

4 Conclusions

We have presented a prototype of mobile DSS for GDM problems based on dynamic decision environments which uses the advantages of mobile Internet technologies to improve the user satisfaction with the decision process and develop decision processes at anytime and anywhere. The system allows to model dynamic decision environments because it incorporates a new tool to manage the changes of alternatives in the set of solution alternatives through decision process. We have used mobile phones as the device used by the experts to send their preferences but the structure of the prototype is designed to use any other mobile device as PDAs.

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