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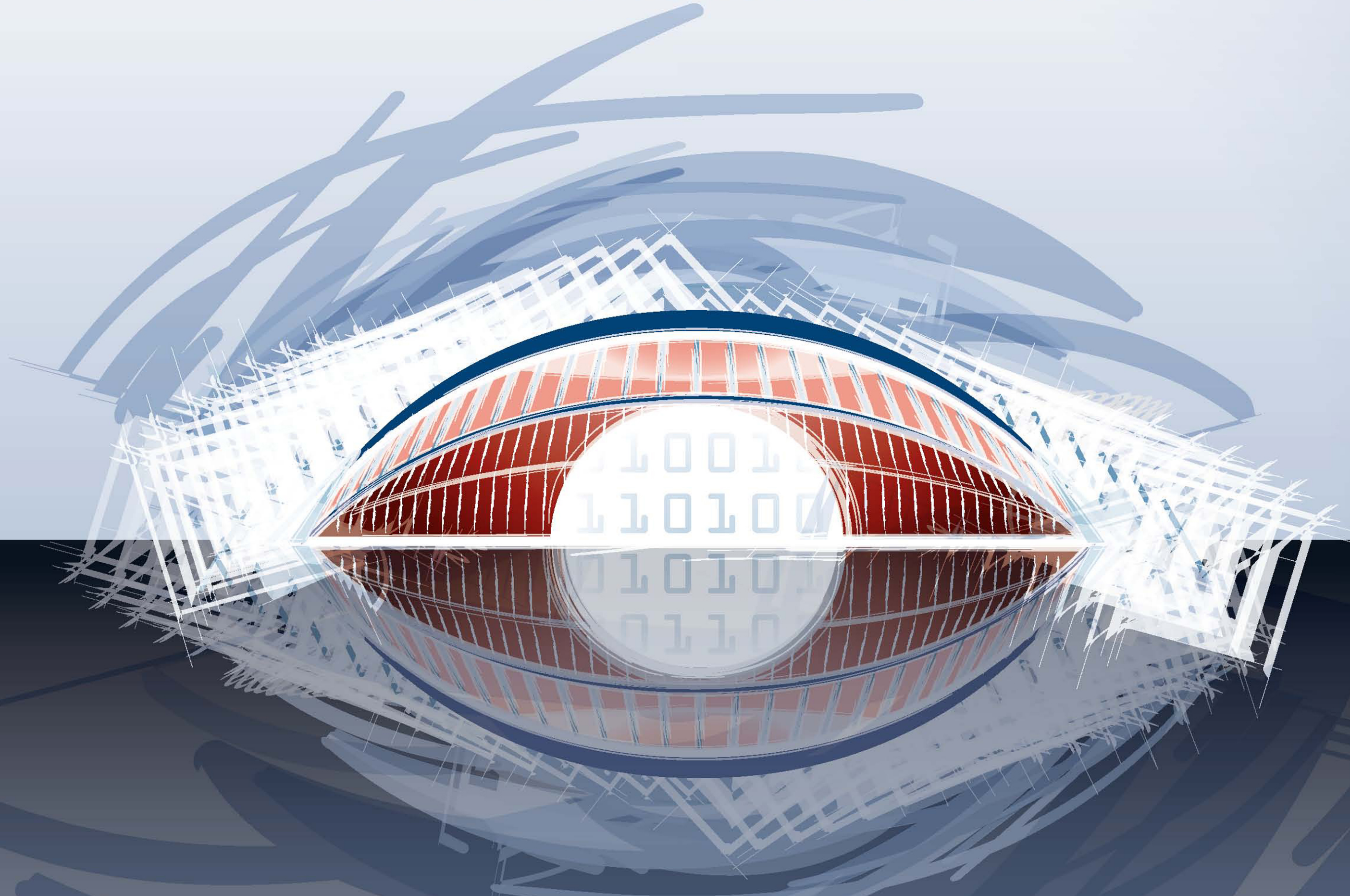

Actas del III Simposio sobre Lógica Fuzzy y Soft Computing

| LFSC2010 | (EUSFLAT)

EDITORES

Luis Martínez, Edurne Barrenechea, Macarena Espinilla, Jesús Alcalá, Victoria López, Manuel Mucientes, José Ángel Olivas, Rosa Mª Rodríguez

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A new mobile decision support system to manage dynamic decision situations

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Abstract

The aim of this contribution is to present a new prototype of decision support system based on mobile technologies and dynamic information. There are a large number of scenarios in which the deployment of decision support systems on mobile devices is desirable. So, users can run the system on their own mobile devices in order to provide their preferences at anytime and anywhere. The system incorporates a mechanism that allows to manage dynamic decision situations in which some information about the problem is not constant through the time, it gives more realism to decision processes with high or dynamic set of alternatives. In this prototype we allow the experts to use linguistic preference relations to express their preferences.

1 Introduction

Group Decision Making (GDM) arises from many real world situations. Thus, 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, Artificial Intelligence, Soft Computing, and so on. In these situations, there is a problem that can be solved in different ways and a group of experts trying to achieve a consensual solution. To do this, experts have to express their preferences by means of a set of assessments over a set of alternatives.

In the last years, the interaction human-technology has had several significant advances. The spread of mobile devices has increased accessibility to data and, in turn, influenced the time and the way in which users make decisions. 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). So, the application of the latest technologies extends opportunities and allows to carry out consensual processes where previously could not be correctly addressed. We assume that if the communications are improved the decisions will be upgraded, because the discussion could be focussed on the problem with less time wasted on unimportant issues [12, 14].

Several authors have provided interesting results on GDM with the help of fuzzy theory [5, 10, 11]. There are decision situations in which the experts' preferences cannot be assessed precisely in a quantitative form but may be in a qualitative one, and thus, the use of a *linguistic approach* is necessary [3, 10, 11]. The *linguistic approach* is an approximate technique which represents qualitative aspects as linguistic values by means of *linguistic variables*, that is, variables whose values are not numbers but words or sentences in a natural or artificial language.

In this contribution we present a prototype of mobile decision support system (DSS) to deal automatically with dynamic GDM problems based on mobile technologies. At every stage of the decision process, users, in order to reach a common solution, receive recommendations to help them to change their preferences and they are able to send their updated preferences at any moment. Additionally, to better simulate real decision making processes, the mobile DSS includes a tool to manage dynamic sets of alternatives [13].

In order to do this, the paper is set out as follows. Some preliminary aspects about GDM models, linguistic approach and mobile technologies usage in GDM problems are presented in Section 2. Section 3 defines the prototype of a mobile DSS. Finally, in Section 4 we point out our conclusions.

2 Preliminaries

In this section we present some considerations about GDM problems, the fuzzy linguistic approach and the use of mobile technologies in consensual processes.

2.1 GDM problems

In a GDM problem we have a finite set of feasible alternatives. $X = \{x_1, x_2, \ldots, x_n\}$, $(n \geq 2)$ and the best alternatives from X have to be identified according to 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 are composed by two different processes [4, 10] (see Fig 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 among the 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. Furthermore, the selection process is composed of two different phases:

   (a) Aggregation phase: This phase uses an aggregation operator in order to transform the individual preferences on the alternatives into a collective preference.

   (b) Exploitation phase: This phase transforms the collective preference into a partial ranking of alternatives that helps to make the final decision.

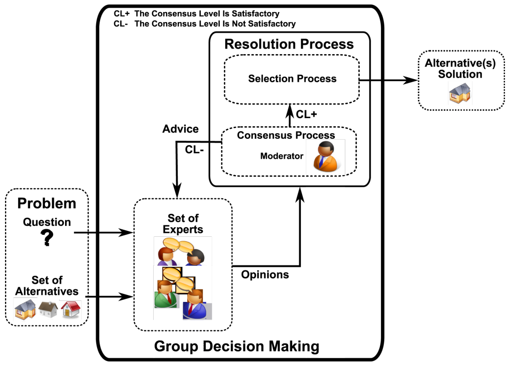

Figure 1: Resolution process of a GDM problem

2.2 Fuzzy linguistic approach

There are situations in which the information cannot be assessed precisely in a quantitative form but may be in a qualitative one. For example, when attempting to qualify phenomena related to human perception, we are often led to use words in natural language instead of numerical values, e.g. when evaluating quality of a restaurant, terms like *good*, *medium* or *bad* can be used. In other cases, precise quantitative information cannot be stated because either it is unavailable or the cost for its computation is too high and an "approximate value" can be applicable, eg. when evaluating the speed of a car, linguistic terms like *fast*, *very fast* or *slow* can be used instead of numeric values [3]. The use of Fuzzy Sets Theory has given very good results for modelling qualitative information [15].

Fuzzy linguistic modelling is a tool based on the concept of linguistic variable to deal with qualitative assessments. It has proven its usefulness in many problems, e.g., in decision making, quality evaluation, information retrieval models, etc. Ordinal fuzzy linguistic modelling [8] is a very useful kind of fuzzy linguistic approach proposed as an alternative tool to the traditional fuzzy linguistic modelling which simplifies the computing with words process as well as linguistic aspects of problems. It is defined by considering a finite and totally ordered label set $S = \{s_i\}, i \in \{0, ..., g\}$ in the usual sense, i.e., $s_i \geq s_j$ if $i \geq j$, and with odd cardinality (usually 7 or 9 labels). The mid term represents an assessment of "approximately 0.5", and the rest of the terms are placed symmetrically around it. The semantics of the label set is established from the ordered structure of the label set by considering that each label for the pair (s_i, s_{g-i}) is equally informative [3]. For example, we can use the following set of seven labels to represent the linguistic information:

$S = \{$ N=*Null*, VL=*Very Low*, L=*Low*, M=*Medium*, H=*High*, VH=*Very High*, P=*Perfect*$\}$.

In any linguistic model we also need some management operators for linguistic information. An advantage of the ordinal fuzzy linguistic modeling is the simplicity and speed of its computational model. It is based on the symbolic computational model [8] and acts by direct computation on labels by taking into account the order of such linguistic assessments in the ordered structure of labels. Usually, the ordinal fuzzy linguistic model for computing with words is defined by establishing i) a negation operator and ii) comparison operators based on the ordered structure of linguistic terms. Eventually, using these operators it is possible to define automatic and symbolic aggregation operators of linguistic information, as for example the LOWA operator [9].

In a GDM problem the experts can present their opinions using different elements of preference representation (preference orderings, utility functions or preference relations) [5], but in this contribution, we assume that the experts give their preferences using fuzzy linguistic preference relations.

A Fuzzy linguistic Preference Relation (FLPR) P^i given by an expert e_i is a fuzzy set defined on the product set $X \times X$, that is characterized by a linguistic membership function

$$\mu_{P^i} : X \times X \longrightarrow S$$

where the value $\mu_{P^i}(x_l, x_k) = p^i_{lk}$ is interpreted as the linguistic preference degree of the alternative x_l over x_k for the expert e_i.

2.3 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 [12, 14].

To support the new generation of decision makers and to add real-time process in the GDM problem field, 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 [13].

3 A new mobile decision support system

In this section, we present the implemented prototype, explaining the architecture and the work flow that summarizes the functions of this system.

A DSS can be built in several ways, and the used technology determines how a DSS has to be developed. The most used architecture for mobile devices is the "Client/Server" architecture, where the client is a mobile device. The client/server paradigm is founded on the concept that clients (such as personal computers, or mobile devices) and servers (computers) are both connected by a network enabling servers to provide different services for the clients. When a client sends a request to a server, this server processes the request and sends a response back to client.

We have chosen a *thick-client* model for our implementation. This allows us to use the software in all the mobile devices without taking into account the kind of browser. Furthermore, the technologies that we have used to implement the prototype comprise Java and Java Midlets for the client software, PHP for the server functions and MySQL for the database management.

So, the prototype allows user to send his/her preferences by means of a mobile device, and the system returns to the experts the final solution or recommendations to increase the consensus levels, depending of the status of the decision process. An important aspect is that the user-system interaction can be done anytime and anywhere which facilitates expert's participation and the resolution of the decision process. In what follows, we describe the client and server of the prototype in detail.

3.1 Client side

The client software shows the next seven interfaces to the experts:

- *Authentication:* The device asks a user and a password to access the system.
- *Connection:* The device must be connected to the network to send/receive information to the server.
- *Problem description:* When a decision process is started, the device shows to the experts a brief description about the problem and the set of alternatives.
- *Insertion of preferences:* The device will have a specific interface to insert the linguistic preferences using a set of labels. To introduce or change the preferences on the interface, the user has to use the keys of the device (see Fig 2).

Figure 2: Insertion of preferences

- *Swap of Alternatives:* When a new alternative appears in the environment of the problem because some dynamic external factors have changed and this alternative deserves to be a member of the discussion subset or when an alternative have a low dominance degree to the current temporary solution of consensus, the system asks the experts if they want to modify the discussion subset by swapping these alternatives. The experts can assess if they agree to swap the alternatives sending their answer to the question received (see Fig 3). If most of the experts agree, the server updates the set of alternatives and each expert has to send his preferences about the new one.

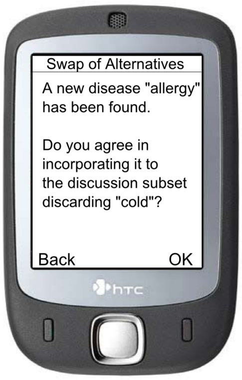

Figure 3: Swap of alternatives

- *Feedback:* When opinions should be modified, the device shows experts the recommendations and allows experts to send their new preferences (see Fig 4).

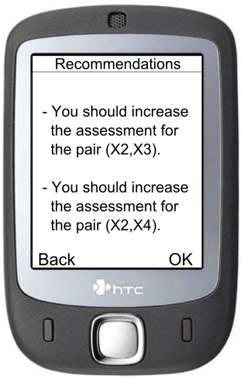

Figure 4: Recommendations

- *Output:* At the end of the decision process, the device will show the set of solution alternatives as an ordered set of alternatives (see Fig 5).

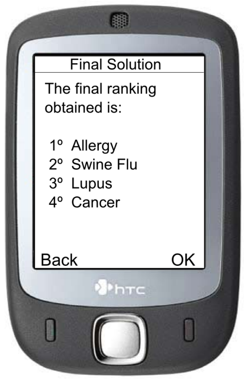

Figure 5: Final solution

On the technical side of the development of the client part, it is worth noting that the client application complies with the MIDP 2.0 specifications [1] and that the J2ME Wireless Toolkit 2.2 [2] 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 using a JAVA-enabled mobile phone on a GSM network using a GPRS-enabled SIM card. The MIDP application is packaged inside a JAVA archive (JAR) file, which contains the application's 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 our this prototype.

3.2 Server side

The server is the main side of the prototype. It implements the main modules and the database that stores the problem data (experts and alternatives) as well as problem parameters, that are introduced at the beginning by the moderator, and the information generated during the decision process. The communication with the client to receive/send information from/to the experts is supported by mobile Internet (M-Internet) technologies (see Fig. 6). Concretely, the three modules of the server are:

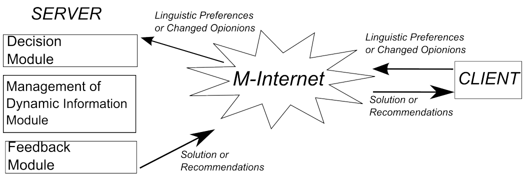

Figure 6: *Server modules*

3.2.1 Decision module

In this contribution, we assume that the experts give their preferences using FLPRs. Once experts have sent their preferences, the server starts the decision module to obtain a temporary solution of the problem. In this module the consensus measures are also calculated. This module has two different processes: 1) *selection process* and 2) *consensus process.*

1. *Selection Process:* This process has two different phases:

   (a) Aggregation phase:

   This phase defines a collective preference relation, $P^c = (p^c_{lk})$, obtained by means of the aggregation of all individual linguistic preference relations $\{P^1, P^2, \ldots, P^m\}$. It indicates the global preference between every pair of alternatives according to the majority of experts' opinions. The aggregation is carried out by means of a LOWA operator ϕ_Q guided by a fuzzy linguistic non-decreasing quantifier Q [9]:

   $$p^c_{lk} = \phi_Q(p^1_{lk}, \ldots, p^m_{lk})$$

   (b) 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 these two choice degrees of alternatives on the collective preference relation [8]:

   - $QGDD_l$: This quantifier guided dominance degree quantifies the dominance that one alternative x_l has over all the others in a fuzzy majority sense.
   - $QGNDD_l$: This quantifier guided non-dominance degree gives the degree in which each alternative x_l is not dominated by a fuzzy majority of the remaining alternatives.

2. *Consensus Process:*

   We assume that the consensus is a measurable parameter whose highest value corresponds to unanimity and lowest one to complete disagreement. We use some consensus degrees to measure the current level of consensus in the decision process. They are given at three different levels [4, 10]: pairs of alternatives, alternatives and relations. The computation of the consensus degrees is carried out as follows:

   (a) For each pair of experts, e_i, e_j $(i < j)$, a similarity matrix, $SM^{ij} = (sm^{ij}_{lk})$, is defined where $sm^{ij}_{lk} =$

   $$1 - \frac{|I(p^i_{lk}) - I(p^j_{lk})|}{g}.$$

   (b) A consensus matrix, CM, is calculated by aggregating all the similarity matrices using the arithmetic mean as the aggregation function $\bar{x}$. $cm_{lk} = \bar{x}(sm^{ij}_{lk})$ where $(i = 1, ..., m-1,\ j = i+1, ..., m)$.

   (c) Once the consensus matrix, CM, is computed, we proceed to calculate the consensus degrees:

      i. *Consensus degree on pairs of alternatives, cp_{lk}*. It measures the agreement on the pair of alternatives (x_l, x_k) amongst all the experts: $cp_{lk} = cm_{lk}$.

ii. *Consensus degree on alternatives, ca_l.* It measures the agreement on an alternative x_l amongst all the experts: $ca_l = \frac{\sum_{k=1}^{n} cp_{lk}}{n}$.

iii. *Consensus degree on the relation, cr.* It measures the global consensus degree amongst the experts' opinions: $cr = \frac{\sum_{l=1}^{n} ca_l}{n}$.

Initially, in this consensus model we consider that in any nontrivial GDM problem the experts disagree in their opinions so that decision has to be viewed as an iterative process. This means that agreement is obtained only after some rounds of consultation. In each round, we calculate the consensus measures and check the current agreement existing among experts using cr.

3.2.2 Management of dynamic information module

Classical GDM models are defined in static frameworks. In order to make the decision making process more realistic, this module is able to deal with dynamic parameters in decision making. The main parameter that could vary through the decision making process is the set of alternatives of the problem because it could depend on dynamical external factors like the traffic [7], or the meteorological conditions [6], and so on. In such a way, we can solve dynamic decision problems in which, at every stage of the process, the discussion is centered on different alternatives.

This tool allows to introduce new alternatives in the discussion subset, but this change has to be approved by the experts. To do so, the mechanism has two phases. At the first one, the system identifies the new alternative to include in the set of discussion alternatives (discussion subset) and the worst alternative of the current discussion subset. The second one is to ask experts about if they agree the replacement and updating the discussion subset [13].

3.2.3 Feedback module

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 consensus level. This mechanism is able to substitute the moderator's actions in the consensus reaching process. The main problem for the feedback mechanism 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. To do that, we compute others consensus measures, called proximity measures [4, 10].

These measures evaluate the agreement between the individual experts' opinions and the group opinion. To compute them for each expert, we need to use the collective FLPR, $P^c = (p^c_{lk})$, calculated previously.

1. For each expert, e_i, a proximity matrix, $PM^i = (pm^i_{lk})$, is obtained where

$$pm^i_{lk} = 1 - \frac{|I(p^i_{lk}) - I(p^c_{lk})|}{g}.$$

2. Computation of proximity measures at three different levels:

   (a) *Proximity measure on pairs of alternatives, pp^i_{lk}.* It measures the proximity between the preferences on each pair of alternatives of the expert e_i and the group: $pp^i_{lk} = pm^i_{lk}$.

   (b) *Proximity measure on alternatives, pa^i_l.* It measures the proximity between the preferences on each alternative x_l of the expert e_i and the group: $pa^i_l = \frac{\sum_{k=1}^{n} pp^i_{lk}}{n}$.

   (c) *Proximity measure on the relation, pr^i.* It measures the global proximity between the preferences of each expert e_i and the group: $pr^i = \frac{\sum_{l=1}^{n} pa^i_l}{n}$.

These measures allow us to build a feedback mechanism so that experts change their opinions and narrow their positions.

4 Conclusions

We have presented a prototype of Mobile DSS for dynamic GDM problems based on dynamic sets of alternatives and tools of computing with words, which uses the advantages of M-Internet technologies to improve the user satisfaction with the consensual process. With this prototype, we shall develop decision processes in a flexible way, that is, we can manage decision situations in dynamic environments at anytime and anywhere.

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