A Decision Support System Based on Mobile Internet

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Abstract

The aim of this paper is to present a model of Mobile Decision Support System where the preferences about alternatives can be provided, by the experts using Mobile Internet devices such as mobile phones or PDAs. Experts' preferences can be represented using different preference elements: preference orderings, fuzzy preference relations, multiplicative preference relations and utility functions. A prototype of mobile decision support system has been developed to automatically support the decision process. As the decision support system is developed to make use of mobile technologies, the decision process is improved and can be carried out faster as it can be used anytime and anywhere.

Keywords: Group decision making, mobile internet, decision support system.

1 Introduction

A decision making process, consisting in deriving the best option from a feasible set, is present in just about every conceivable human task. As a result, the study of decision making is necessary and very 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.

It is obvious that the comparison of different actions according to their desirability in decision problems, in many cases cannot be done, by using a single criterion or an unique person. Thus, we interpret the decision process in the framework of group decision making (GDM) [11]. This has led to numerous evaluation schemes, and has become a major concern of research in decision making. Several authors have provided interesting results on GDM with the help of fuzzy theory, for example [6, 9, 11].

The central goal of decision support systems (DSS) is to process and provide suitable information in order to support individuals or organizations in decision making [7]. Therefore, appropriate mobile DSS could bridge the gap and provide additional value to users as timely information supply and supported decision making should provide a basis for more successful transactions [12].

The last decade has seen significant advances in the way human interact with technology. Users of computers are no longer constrained to the office desktop, but can have much more flexible access to technology almost anywhere and anytime. The spread of e-services and wireless or mobile devices has facilitated a new way of using computers, increased accessibility to data and, in turn, influenced the way in which users make decisions while on the move, the opportunities for decision support have been extended [5]. 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 are not shared with others [2].

The aim of this paper is to present a prototype of mobile DSS to deal automatically with GDM problems based on Mobile Internet technologies. In order to build a flexible framework and to give a larger freedom degree to represent the preferences, we will use a GDM model in which the preferences can be provided in any of these four ways [3, 8]: *preference orderings, fuzzy preference relations, multiplicative preference relations or utility functions*. To solve GDM problems in this framework, firstly, we make the information uniform, using fuzzy preference relations as the main element on the uniform representation of the preferences, and secondly, we apply the selection process and the consensus process to obtain a final solution with a high consensus degree. This mobile DSS implements the GDM model presented in [10], including some new improvements. Some of these improvements are directly derived from the advantages that mobile technologies provide,(anywhere and anytime use), and will allow the development of more dynamic GDM processes. In fact, at every stage of the decision process, users will be informed with updated data about current stage of the decision process, they will receive recommendations to help them to change their preferences, they will be able to send their updated preferences at any moment, thus improving the user participation in the GDM process.

In order to do this, the paper is set out as follows. The Mobile Internet technologies are presented in Section 2. Section 3 presents the prototype of mobile DSS. And, finally, Section 4 shows our conclusions.

2 Mobile Internet: Advantages and Limitations

Mobile communication systems are characterized by a variety of features. They differ from each other in the degree of their complexity, the level of the offered services and operation costs. The attributes of all mobile communication systems is the mobility of at least one of the connection users and the lack of wired connection of this user's terminal with the remaining part of system.

The Mobile Web refers to the World Wide Web as accessed from mobile devices such as cell phones, PDAs, and other portable gadgets connected to a public network. So, access to web services no longer requires a desktop computer.

With the fast increase of the Internet usage, the growing penetration of wireless devices, and the fast technological innovation, wireless technology shifts the world of wired internet to the wireless Mobile Internet, which is often referred to as M-Internet. The following list shows the different advantages that this technologies can provide.

1. Internet has provided an easy and effective way of delivering information and services to millions of users who are connected to wired network. Evidently, this wired network addresses two major constraints: time and place. These limitations have raised the issue of the mobile internet, which enables users to access information from any place at any moment using a mobile wireless device. The possibility to access to this kind services in wireless environments provides a great mobility to the users. This mobility can increase the productivity increasing agility of some tasks, can allow to save displacements and infrastructure's costs, can improve the business processes, can ease the decision making processes obtaining more dynamic and precise solutions, and even it can improve the offered services.

2. The mobile computing paradigm has several interesting and important applications for business, telecommunications, real-time control systems, remote operations and in accessing the Internet [5, 12, 13].

3. Recently, the fast technological innovation made it possible to provide secure, fast and quality communication through the wireless network. Mobile devices were a few years ago considered a luxury, but have at nowadays become a conventional communication tool. Moreover, the devices that used to deliver limited information are now able to provide a wide range of information and services such as e-mail, banking, entertainment and even games.

However, Mobile Web access today still suffers from some interoperability and usability problems. This is partly due to the small physical size of the screens of mobile devices and partly due to the incompatibility of many mobile devices with both computer operating systems and the format of much of the information available on the Internet.

To make use of M-Internet in the best way, several conditions need to be fulfilled. The first condition is the widespread use of mobile devices that connect individuals to the mobile network and the contents that provide useful information and services to users. In addition, the technological support in terms of speed, communication quality and security are also important in the development of the M-Internet [2].

Some of the limitations that current mobile services have to face are:

1. *Small screen size:* It is difficult or impossible to properly adapt text and graphics prepared for the standard size of a desktop computer screen with current information standards.

2. *Lack of windows:* On mobile web only one page can be displayed at a time, and pages usually can only be viewed in the sequence they were originally accessed.

3. *Navigation:*Usual mobile devices do not use a mouse like pointer, but rather simply an up and

down function for scrolling, thereby limiting the flexibility in navigation.

4. *Format of accessible pages:* Many sites that can be accessed on a desktop cannot on a mobile device. Many devices cannot show pages with a secured connection, Flash or other similar elements, PDFs, or video sites.

5. *Speed:* On most mobile devices, the speed of service is very slow, often slower than dial-up internet access.

6. *Size of messages:* Many devices have limits on the number of characters that can be sent in a single message.

The Mobile Web mainly uses lightweight pages written in Extensible Hypertext or Wireless Markup Language (XHTML) or (WML), to deliver content to mobile devices. However, new tools such as Macromedia's Flash Lite or Sun's J2ME enable the production of richer user interfaces customized for mobile devices.

3 A Prototype of Mobile DSS

While decision support systems have typically been associated with desktop systems and involve considerable processing, the development of new compact and mobile technologies provides new opportunities to develop this kind of DSS over M-Internet [1]. This section briefly describes the prototype of Mobile DSS which implements the GDM model with multiple elements of preference representation defined in [10] and uses the advantages of M-Internet technologies.

3.1 A GDM Problem with Different Elements of Preference Representation

In a GDM problem we have a finite set of alternatives. $X = \{x_1, x_2, \ldots, x_n\}$, $(n \geq 2)$ and these alternatives have to be classified from best to worst, using the information given by a set of experts, $E = \{e_1, e_2, \ldots, e_m\}$, $(m \geq 2)$. As each expert, $e_k \in E$, has his own ideas, attitudes, motivations and personality, it is quite natural to think that different experts will give their preferences in a different way. This leads us to assume that the experts' preferences over the set of alternatives, X, may be represented in different ways. In [3, 8] a GDM model assuming that the experts can present their preferences using any of the following elements of preference representation was presented:

- *A preference ordering of the alternatives.* In this case, an expert, e_k, gives his preferences on X as an individual preference ordering, $O^k = \{o^k(1), ..., o^k(n)\}$, where $o^k(\cdot)$ is a permutation function over the index set, $\{1, ..., n\}$, for the expert, e_k. Therefore, according to this point of view, an ordered vector of alternatives, from best to worst, is given.

- *A fuzzy preference relation.* With this representation, the expert's preferences on X is described by a fuzzy preference relation, $P^k \subset X\text{x}X$, with membership function, $\mu_{P^k} : X\text{x}X \rightarrow [0, 1]$, where $\mu_{P^k}(x_i, x_j) = p^k_{ij}$ denotes the preference degree of the alternative x_i over x_j.

- *A multiplicative preference relation.* In this case, the expert's preferences on X are described by a preference relation, $A^k \subset X\text{x}X$. The intensity of preference , a^k_{ij}, is measured using a ratio scale, particularly the 1 to 9 scale; $a^k_{ij} = 1$ indicates indifference between x_i and x_j, $a^k_{ij} = 9$ indicates that x_i is absolutely preferred to x_j, and $a^k_{ij} \in 2, 3, \ldots, 8$ indicates intermediate evaluations.

- *An utility function.* In this case, an expert, e_k, gives his preferences on X as a set of n utility values, $U^k = \{u^k_i,\ i = 1, ..., n\}$, $u^k_i \in [0, 1]$, where u^k_i represents the utility evaluation given by the expert e_k to the alternative x_i .

Usual resolution methods for a GDM problems are composed by two different processes [9] (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.

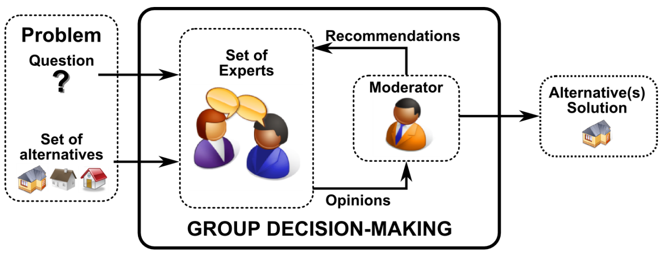

Figure 1: *Resolution process of a GDM*

As it was shown in [3, 8], when the information provided by a group of experts is assumed to be of a diverse nature, we need to make the information uniform before applying the consensus and selection processes in order to obtain the solution alternatives. Assuming the above fact, in [10] a GDM model was proposed, which incorporated i) a process to make the preferences uniform that used some transformation functions between the different preference elements and fuzzy preference relations as the base element of the uniform representation, ii) a selection process based on quantifier guided aggregation operators to obtain the ranking of solution alternatives, and iii) a consensus process with a feedback mechanism to help experts in the consensus reaching process. Its operation scheme is shown in Figure 2.

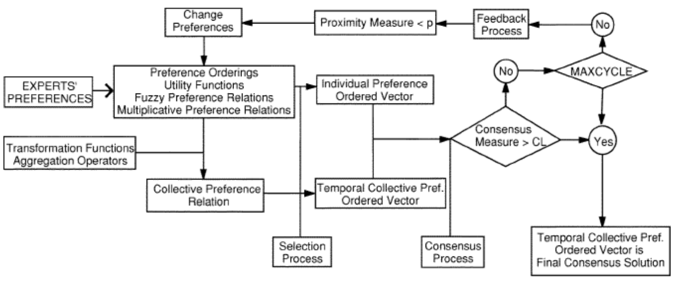

Figure 2: *Operation of GDM model with multiple elements of preference representation*

3.2 Prototype of the Mobile DSS

According to GDM model proposed in [10] the prototype of the Mobile DSS should to present an operation structure based three main modules, which receive/send information from/to the experts through M-Internet technologies (see Figure 3).

1. Uniform Information Module, that makes the information uniform using fuzzy preference relations as the base element of the uniform representation .
2. Selection Module, that returns the solution set of alternatives in each stage of decision process.
3. Consensus Module, that determines if the adequate agreement degree has been reached and the decision process must finish by applying the selection process, or, in other case, if we must do a new round of consensus using the feedback mechanism that generates recommendations to change preferences.

The user sends his/her preferences to Mobile DSS by means of a mobile device, and the system returns expert the final solution or recommendations or preferences of other experts or consensus levels, depending of stage of decision process. An important aspect is that the user-system interaction is done in anytime and anywhere and this facilitates expert's participation and the resolution of the decision process.

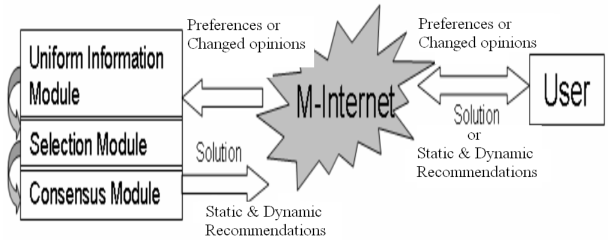

Figure 3: *Operation structure of prototype of Mobile DSS*

A DSS can be built of several ways, and the technology used determines how a DSS is developed [7]. There exist several infrastructures and platforms which can form the technological basis for a DSS: "Mainframe computers", "Client/server", "Internet and Web based systems", or "mobile devices and services" are some kinds of architectures [12].

A good architecture for our prototype of Mobile DSS, is a "Client/Server" architecture, where the client is a mobile device. The client/server paradigm is founded on the concept that clients (such a personal computers, or a mobile device) and servers (powerful personal computer) 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. Furthermore, the technologies used to implement the prototype of Mobile DSS comprise java and java midlets for the client software, Php for the server functions and MySql for the database management.

In what follows, we describe in detail the client and server of prototype of Mobile DSS.

1. **Client**

   We suggest a thin client model, this model is a client device in the client-server architecture networks which depends primarily on the central server for processing activities, and mainly on converging input and output between the user and the remote server. Although this prototype is designed to operate on several mobile devices, such as GSM or UMTS mobile phones or PDA devices that uses mobile network infrastructures and mobile messaging services that fix the communication protocols to use, initially, we have implemented it for mobile phones with Internet connection. The software installed in the client has to meet the next five requirements.

- Connection: The device can be connected to the network to send/receive information to the server.
- Authentication: The device will ask for an user and password to access the system (see Figure 4).

Figure 4: *Authentication and M-Internet connection*

- Interface: The device will have four different interfaces, one for each different element of preference representation (see Figures 5 and 6).

Figure 5: *Insertion of preferences*

- Feedback: When opinions must be modified, the device shows experts the recommendations and lets experts to send the new preferences (see Figure 7).

Figure 6: *Insertion of preferences*

Figure 7: *Recommendations and Final Solution*

- Output: At the end of the decision process, the device will show the set of solution alternatives (see Figure 7).

Some examples of use for this software can be decision making processes where the experts have not the possibility of gathering together, for example doctors of different countries that have to obtain a prediction for a disease or managers of different cities that have to choose the best applicant for a working place.

The client application complies with the MIDP 2.0 specifications. The J2ME wireless toolkit 2.2 provided by SUN was used in the development phase. The wireless toolkit is a set of tools that provide J2ME developers with the emulation environments, documentation, and examples to develop MIDP-compliant applications. The application was later tested using the 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 applications class and resource files. It is this JAR file that is actually downloaded to the physical device (mobile phone) along with the JAVA application descriptor file.

2. **Server**

   The server is the most important part of the DSS. It implements the uniform information module, the consensus module, the selection module, the database that stores all data of problem as experts' data, alternative data, preferences, consensus measures, recommendations, consensus parameters, selection parameters, ect,. Therefore, the server has to carry out the following functions:

   - **Verify the user messages and store the main information:** When a expert wants access to the system, he has to send a message through M-Internet using his mobile device. This message is composed by information of authentication (login and password) and his preferences about the problem, using any of these four ways: *preference orderings, fuzzy preference relations, multiplicative preference relations or utility functions.*

     The message is verified by the server, that check the login and password in the database using MD5 to encrypt the passwords. If the authentication process is correct, the rest of the information of the message is stored in the database, and the server check if all the experts have sent their preferences and the consensus stage can start.
   - **Make uniform the experts' preferences:** Using transformation functions to convert all the kind of preferences into fuzzy preference relation, the server is able to make the information uniform, and save this information in the database, that will be used later by the selection module.
   - **Calculate the set of solution alternatives:** Once the information is uniform, the server can apply the selection process to obtain a temporary solution of the problem. This process has two phases: i) Aggregation and ii) Exploitation. In the aggregation phase, the collective fuzzy preference relation is obtained. In the next phase, we apply the exploitation process to obtain the quantifier guided dominance degree of alternatives acting over the collective fuzzy preference relation, that allows to establish an order in the alternatives to obtain the ranking of temporary solutions, from best to worse. All this information about the temporary solution is saved in the database.
   - **Calculate the consensus measures:** In this step, the consensus and proximity measures are calculated by the server and saved in the database.
   - **Control the consensus stage:** If the consensus measure has reached the minimum consensus level defined as a parameter of the problem, the consensus process would be stopped and this temporary collective solution would be the final consensual solution. In other case, the consensus process should continue. In order to avoid that the collective solution does not converge after several discussion rounds the prototype incorporate a maximum number of rounds to develop, MAXCYCLE.
   - **Generate the recommendations:** The ranking of experts according to the proximity of their individual solutions to the temporary collective solutions and the recommendations for the experts that must change their preferences are calculated in this step. This is a feedback mechanism and these results are saved in the database and sent to the experts' mobile devices for help them to change their preferences and in this way, the consensus process will be convergent and the solution will have a high consensus degree quickly.

4 Conclusions

We have presented a prototype of Mobile DSS for GDM problems based on multiple elements of preference representation, which uses the advantages of M-Internet technologies to improve the user satisfaction with the decision process and to develop decision processes in anytime and anywhere. We have used phones as device to send the experts' preferences but the structure of the prototype is designed to use any mobile device as PDAs.

In the future, we shall incorporate in the prototype tools to manage incomplete and inconsistent preferences.

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