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A Fuzzy Linguistic Decision Support System to Aid Users in E-Commerce Activities

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Abstract— *With the recent spreading of social networks and digital communities, the Web has a new business model for providing free content-sharing services. Using the power of the masses and the collective intelligence, Web 2.0 sites have created enormous e-commerce opportunities for marketing and advertising. Thus, there is still a necessity of developing tools to help users to reach good decisions in such frameworks. We propose to manage this collective intelligence with a Decision Support System (DSS). It allows that users with similar user profiles that the potential customer can advice him/her according with their own experiences in their e-commerce activities. From user preferences the DSS obtains a collective advice that helps customers to make decisions related with their e-commerce activities.*

Keywords: Group decision making, e-commerce, decision support system, linguistic approach, web 2.0, social network

1. Introduction

The global build of Internet connectivity and growing availability of computing and communication devices have made the World Wide Web a new virtual borderless continent. New Web technologies have allowed the creation of many different services where users from all over the world can join, interact and produce new contents and resources. One of the most recent trends, the so called *Web 2.0* [16], represents a paradigm shift in how people use the web which comprises a set of different web development and design techniques. It allows the easy communication, information sharing, interoperatibility and collaboration in this new virtual environment. Web 2.0 Communities, that can take different forms as Internet forums, groups of blogs, social network services and so on, provide a platform in which users can collectively contribute to a Web presence and generate massive content behind their virtual collaboration [13].

Due to the above new Web features, we can think about great potentials and challenges for the future of some internet business like electronic commerce (e-commerce). E-commerce is the buying and selling of goods and services on the Internet, and it is now spreading into all walks of life. Even, users can view, select and pay for online services in a mobile framework [1], [13]. New challenges about e-commerce involves new technologies, services and business models. Social shopping sites emerged as the latest developments to leverage the power of social networking with online shopping. Users on social shopping sites can post product recommendations, create wish lists, post photos, make purchases, and form social shopping communities [13].

We propose to incorporate new services (web 2.0) and technologies (mobile devices) in a decision support system (DSS) for advising customers in their e-commerce experiences on-time. The central goal of DSSs [5] is to process and provide suitable information in order to support individuals or organizations in their decision making tasks like to decide where travel in holidays or shopping elections. Usually, people bring their mobile devices with them anywhere. So, they have the possibility to use some mobile services wherever they go. Studies of mobile commerce suggest that there is a general customer interest in the services that it provides, like shopping and banking applications [4], [17]. Its adoption, however, has been slower than expected. Mobile phones impose very different constraints than desktop computers. It has been argued that this stems from complexity of the transactions, perceived lack of security, lack of user friendly mobile portals, etc. [8], [17].

Due to the big amount of different items and online advertisements, the first problem for the customer is to rank the different alternatives in order to buy the best one taking into account his/her connected partners' advice. This problem can be seen as a group decision making (GDM) problem because it includes all the necessary requirements for this kind of problems.

GDM models are used to obtain the best solution(s) for a problem according to the information provided by some decision makers (expert). Usually, each expert may approach the decision process from a different angle, but they have a common interest in reaching an agreement on taking the best decision. Concretely, in a GDM problem we have a set of different alternatives to solve the problem and a set of experts which are usually required to provide their preferences about the alternatives by means of a particular preference format [11]. In the case of e-commerce advising, the alternatives are the items or services that can be bought by the customer, and the set of experts of the problem are the members connected with the customer's social network.

To deal with the above situations, we present a mobile DSS (MDSS) that could be incorporated as a tool into a social network to help customers in their e-commerce activities. To advise customers in their electronic shopping, the MDSS shows customers the ranking extracted by aggregating the collective intelligence of the virtual community. In such a way, our system allows that the members connected with the customer aid him/her to choose the best good or service of the stock, according to the customer's needs. To represent the preferences provided by the social network members we use a *fuzzy linguistic modelling* [9], [19].Thus, to compute the advices we use computing with words tools based on linguistic aggregation operators [11] and an estimation algorithm to deal with incomplete information [3].

To do so, the paper is set as follows: in section 2 we present our preliminaries, that is, some of the most important characteristics of Web 2.0 Communities and the basic concepts that we use in our paper like GDM problems and computing with words. Section 3 deals with the incorporation of the MDSS as a mobile web 2.0 service. Finally, in section 4 we point out our conclusions.

2. Preliminaries

2.1 New E-Commerce Opportunities Based on Web 2.0

Emerging web and mobile technologies provide the foundation for new e-commerce opportunities and applications. They also generate the push for new enterprise system architectures in order to deploy new Web technologies and transform businesses into e-commerce driven operations. This new framework allows people from all over the globe to meet other individuals which share some of their interests. Thus, virtual communities can be created in order to collaborate, communicate, share information or resources and so on. The Web has become a media supported by advertisers that, in turn, sell their products to users via e-commerce. In digital cyberspace, e-commerce is moving into a new border, mixing physical and digital goods trading. Companies have even created their own digital currencies for online exchange of goods and services [1], [13], [14].

E-commerce is an area of study that has practical applications and a prominent future. Although the Internet bubble has generated some negative sentiment about the industry, many previously unsuccessful e-commerce ventures and business models have now reemerged and become feasible and profitable. With ubiquitous broadband connectivity and powerful personal devices (including PCs, mobile phones, and media players), mobile commerce has become a growing part of our daily lives. More important, endless opportunities still exist to deploy new mobile commerce products and services that are simply impossible without automated Web-based and mobile support [1], [13], [14].

With most online shopping, people have numerous choices when looking for a specific item in which they are interested. Many shoppers use search engines but often get more information than what they really want. In this paper, we want to identify an unexplored market and to create new products and services using mobile tools and collective intelligence to help customers. To do so, we propose a linguistic mobile decision support system that acts like a recommender system where the recommendations are given by other users of the social networking web site who have the same user profile that the customer. This application could improve the customers' satisfaction in their e-commerce activities.

2.2 Group Decision Making Models

A decision making process, consisting in deriving the best option from a feasible set, is present in just about every conceivable human task. 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 GDM.

There have been several efforts in the specialized literature to create different models to correctly address and solve GDM situations. Some of them make use of fuzzy theory as it is a good tool to model and deal with vague or imprecise opinions. Many of those models are usually focused on solving GDM situations in which a particular issue or difficulty is present. For example, there have been models that allow to use linguistic assessments instead of numerical ones, thus making it easier for the experts to express their preferences about the alternatives [11]. Other models allow experts to use multiple preference structures [7] and other different approaches deal with incomplete information situations if experts are not able to provide all their preferences when solving a GDM problem [2], [3], [6].

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 alternative from X has 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 [11]: the first one consists in a *consensus process* in which the experts discuss about the alternatives and express their preferences about them using a particular preference representation format. A special individual (the moderator) checks the different opinions and confirms if there is enough consensus among all the experts. If there is not enough consensus, the moderator urges the experts to re-discuss about the alternatives and to provide a new set of opinions to improve the consensus level in a new consensus round. Once the desired consensus have been reached (or a maximum number of consensus rounds has been reached) the second process, called the *selection process*, starts and the best solution is obtained by aggregating the last opinions from the experts and applying an exploitation step which identifies the best alternative from the aggregated information (see Figure 1):

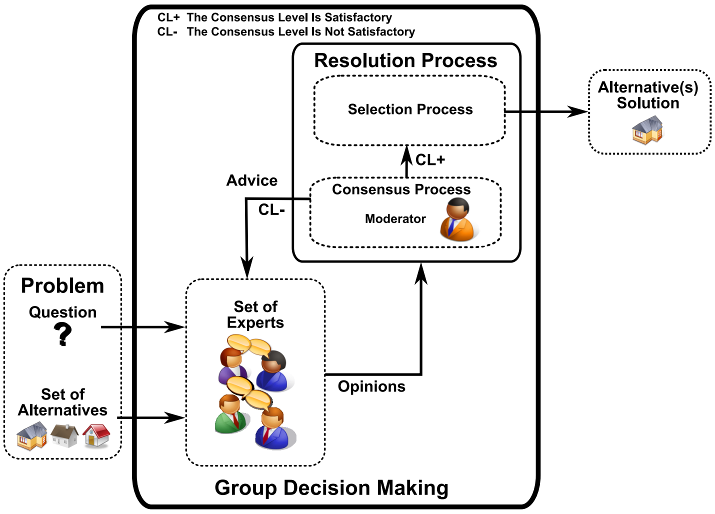

Fig. 1: Resolution process of a GDM

In this paper we center our attention only in the selection process implementation, where the system has to obtain the solution ranking of alternatives from the opinions on the alternatives given by the experts.

2.3 Use of Incomplete Linguistic Information in GDM Problems

There are some situations in which the information may be not quantified due to its nature, and thus, it may be stated only in linguistic terms. Linguistic decision analysis is applied for solving decision making problems under linguistic information. Its application in the development of the theory and method in decision analysis is very beneficial because it introduces a more flexible framework which allows us to represent the information in a more direct and adequate way when we are unable to express it precisely. So, this method has been widely used in decision field [3], [6], [9], [15].

The ordinal fuzzy linguistic modelling [11] is a useful kind of fuzzy linguistic approach proposed as an alternative tool to the traditional fuzzy linguistic modelling [19]. This tool simplifies the computing with words process as well as some 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).

Other different issue arises when each expert has his/her own experience concerning the problem being studied and they could have some difficulties in giving all their preferences. This may be due to an expert not possessing a precise or sufficient level of knowledge of the problem, or because that expert is unable to discriminate the degree to which some options are better than others. In such situations, experts are forced to provide incomplete fuzzy linguistic preference relations (FLPRs) [3], [12]. Therefore, it is of great importance to provide tools to deal with this lack of knowledge in experts' opinions.

We assume that each social network member e_h provides his/her preferences by means of an ordinal FLPR P^h which, depending on the situation, could be incomplete. So, before to start the selection process, we have to fill the gaps of all the missing values by using an additive consistency based estimation process developed in [3].

On the other hand, an useful linguistic aggregation operator is the Linguistic Ordered Weighted Averaging (LOWA) operator which has been extensively used in the literature by its good axiomatic properties [11]. We shall use it in our MDSS.

3. A Mobile Linguistic Decision Support System to Help Users in Their E-Commerce Activities

To develop the MDSS as a Web 2.0 service, the system asks customer his/her current needs (the tool offers a personalized service). Taking into account these needs, together with the community's collective knowledge, the system shows to the customer the ranking through his own mobile device. Therefore, the customer receives a social support to choose the best item for buying. The advise is represented by means of linguistic rankings of shopping alternatives obtained from the individual preference relations provided by the social network members applying a selection process.

To do so, we have chosen a classical "Client/Server" architecture, where the client is a mobile device. What is more, as we want to develop the MDSS like a web service, our implementation has thick client features such as no additional technology investment required, and no risk of client-side software becoming obsolete. There is no need for additional servers, and no unique client-side software or upgrade costs. Its main drawback is that all content cannot be easily delivered to all browsers. Furthermore, the technologies that we have used to implement the prototype comprise Java 2 Micro Edition (J2ME) for the client software, PHP for the server functions and MySQL for the database management.

In what follows, we describe the client interface and the server structure in detail.

3.1 Client Interface

The client software shows a specific interface to the users depending on the kind of user. At first, the user has to introduce his/her password in the system, then, the system decides the kind of interface to show. There are two different interfaces: *Customer interface* and *Member Interface*.

1) *Customer interface:* This interface is designed for the customers that need help with their m-commerce experiences.
   - *Select alternatives:* To introduce the preferred items to buy (see Figure 2 a).
   - *Needs survey:* To choose the importance degree of the item's features (see Figure 2 b).
   - *Output:* At the end of the decision process, the device will show the set of solution alternatives as an ordered set of alternatives marking the most relevant ones (see Figure 3 a).
2) *Member Interface:* This interface is designed for the social network members that can help the potential customers.
   - *Problem description:* The device shows to the members a brief description about the problem and the discussion subset of alternatives.
   - *Insertion of preferences:*Due to the system implements the ordinal fuzzy linguistic representation model, the device has a specific interface to insert the preferences by using a set of labels. To introduce the preferences on the interface, the user has to use the keys of the device (see Figure 3 b).

Fig. 2: a) Selection of alternatives. b) Needs survey

3.2 Server Structure

The web server is the main side of the MDSS. It implements the estimation process, the selection process and the database that stores not only the problem data, but also problem parameters and some 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.

Once the customer has submitted his/her preferred items and his/her current needs, the members connected with him/her have to give their opinions, taking into account the customer's needs, about the alternatives that the customer has selected (see Figure 2). When all the experts have given their opinions using incomplete ordinal FPLRs as element of preferences' representation, the system starts to compute the collective advice.

Fig. 3: a) Displayed ranking advice. b) Insertion of individual advices

3.2.1 Estimation Process

In [3] we develop an additive consistency based estimation process of missing values to deal with incomplete FLPRs defined in a 2-tuple linguistic context. In this paper we adapt it to deal with incomplete FLPRs defined in an ordinal linguistic context.

To deal with incomplete FLPRs we need to define the following sets [12]:

$$\begin{array}{l} A = \{(i,j) \mid i,j \in \{1,\dots,n\} \wedge i \neq j\} \\ MV^h = \{(i,j) \in A \mid p_{ij}^h \text{ is unknown}\} \\ EV^h = A \setminus MV^h \end{array} \quad (1)$$

where MV^h is the set of pairs of alternatives whose preference degrees are not given by expert e_h and EV^h is the set of pairs of alternatives whose preference degrees are given by the expert e_h. We do not take into account the preference value of one alternative over itself as this is always assumed to be equal to $s_{g/2}$.

The subset of missing values that could be estimated in step t of the process, called EMV_t^h (*estimated missing values*), is defined in [3].

When $EMV_{maxIter}^h = \emptyset$, with $maxIter > 0$, the procedure will stop as there will not be any more missing values to be estimated. Furthermore, if $\bigcup_{l=0}^{maxIter} EMV_l^h = MV^h$, then all missing values are estimated, and, consequently, the procedure is said to be successful in the completion of the incomplete FLPR.

In iteration t, to estimate a particular value p_{ik}^h with $(i,k) \in EMV_t^h$, we use the function $estimate\_p(h,i,k)$, that can be studied with detail in [3]. Then, the complete iterative estimation procedure is the following:

ITERATIVE ESTIMATION PROCEDURE

0. $EMV_0^h = \emptyset$
1. $t = 1$
2. while $EMV_t^h \neq \emptyset$ {
3. for every $(i,k) \in EMV_t^h$ {
4. estimate_p(h,i,k)
5. }
6. $t++$
7. }

3.2.2 Selection Process

The selection process implemented computes all the individual preferences to obtain a collective advice. It has two different phases [10]: aggregation and exploitation.

1) Aggregation:
   The aggregation phase defines a collective preference relation, $P^c = \left(p_{ij}^c\right)$, obtained by means of the aggregation of all individual linguistic preference relations $\left\{P^1, P^2, \ldots, P^m\right\}$. It indicates the global preference between every pair of items according to the majority of experts' opinions. The aggregation is carried out by means of a LOWA operator [18], [11].
   A LOWA operator of dimension n is a function $\phi : S^n \rightarrow S$ that has a weighting vector associated with it, $W = (w_1, ..., w_n)$, with $w_i \in [0,1]$, $\sum_{i=1}^{n} w_i = 1$, and it is defined according to the following expression:

$$\phi_Q(p_1, \ldots, p_n) = \sum_{i=1}^{n} w_i \cdot p_{\sigma(i)}, \quad p_i \in S, \qquad (2)$$

   being $\sigma : \{1, ..., n\} \rightarrow \{1, ..., n\}$ a permutation defined on linguistic values, such that $p_{\sigma(i)} \geq p_{\sigma(i+1)}, \forall i = 1, ..., n-1$, that is, $p_{\sigma(i)}$, is the i-highest linguistic value in the set$\{p_1, ..., p_n\}$.
   A natural question in the definition of OWA operators is how to obtain W. In [18] it was defined an expression to obtain W that allows to represent the concept of fuzzy majority by means of a fuzzy linguistic non-decreasing quantifier Q:

$$w_i = Q(i/n) - Q((i-1)/n), \quad i = 1, \ldots, n. \qquad (3)$$

   Therefore, in our model the collective FLPR is obtained as follows:

$$p_{ij}^c = \phi_Q(p_{ij}^1, \ldots, p_{ij}^m) \qquad (4)$$

   We can use the linguistic quantifier *most of* defined as $Q(r) = r^{1/2}$, that generates a weighting vector of n values. As an example with three experts, $W = (0.58, 0.24, 0.18)$. To obtain each collective ordinal linguistic preference value p_{ij}^c we have to do that follows:
   - $p_{ij}^1 = M, \quad p_{ij}^2 = L, \quad p_{ij}^3 = VL \Rightarrow \sigma(1) = 1, \quad \sigma(2) = 3, \quad \sigma(3) = 2$
   - $p_{ij}^c = \Gamma(w_1 \cdot \Gamma^{-1}(p_{ij}^1) + w_2 \cdot \Gamma^{-1}(p_{ij}^3) + w_3 \cdot \Gamma^{-1}(p_{ij}^2)) = \Gamma(0.58 \cdot 3 + 0.24 \cdot 1 + 0.18 \cdot 2) = \Gamma(2.34) = L$
2) Exploitation:
   This phase choose the best alternatives from P^c. In our framework, we need to identify the best item of the set to buy it. Usually, the exploitation in GDM is modeled using *linguistic choice functions* which allow us to characterize the alternatives and to separate the best ones.
   Then, we have to develop two tasks:
   a) Obtain a rank ordering among the alternatives by means of a linguistic choice function. So, we use the choice function called *quantifier guided dominance degree* to rank items from the collective FLPR P^c. This choice function quantifies the dominance that one alternative has over all the others in a fuzzy majority sense [3].
   b) Choose the best alternatives according to the established rank ordering.

When the system has computed all these values, the customer receives them in his mobile device in form of advice (see Figure 3 a):

4. Conclusions

We have presented a MDSS tool based on GDM models as a Web 2.0 service related with e-commerce and collective intelligence that is represented with incomplete FLPRs. This tool uses the advantages of M-Internet communication technologies to advise the customer in their m-commerce experiences and improves the customer satisfaction with the decision of purchase in anytime and anywhere. We have used smartphones as device to send the experts' preferences but the structure of the prototype is designed to use any mobile device as PDAs.

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