Group Decision Making in the Web 2.0: A decision support system design for changeable contexts

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Abstract. This paper presents the design of a decision making support system that is able to work over changeable contexts, that is, it can add and remove experts and alternatives at any time during the group decision making process. Since changes that Internet has experienced with the appearance of Web 2.0 technologies allow people to easily get in touch using the Internet, we have assumed that the experts are not located in the same room and use the Internet to get in contact and make decisions in an organized way. In order to ease the way that experts use to express their preferences, three different representation formats have been used. Moreover, multi-granular fuzzy linguistic modelling has been used in order to allow the experts to choose the preferences precision. Finally, consensus processes have been used to help experts to reach an agreement before selecting a final alternative.

Keywords: Group Decision Making; Multi-granular Fuzzy Linguistic Modelling; Soft Computing; Decision Support Systems

1 Introduction

Group Decision Making is part of our everyday life. From where to go to have lunch to critical company decisions that can make the difference between the success and the failure of a project, most of them are made by a set of people. Therefore, Group Decision Making has become an important field of study since its first appearance in the 70's [1, 2] until nowadays [3–6]. The main purpose of a Group Decision Making process is to rank a set of alternatives using the preferences provided by a set of experts [7]. Traditionally, decisions are made in meetings. Experts meet in the same room and discuss the matter of interest.

Nevertheless, this is not the most optimal way of carrying out this process since experts usually have different responsibilities and schedules making it difficult for them to reunite. In order to solve this issue, experts can use Internet and Web 2.0 technologies to communicate and make decisions independently of their location [8].

Web 2.0 technologies [9] have revolutionized the way that Internet has been initially conceived. They have promoted an Internet framework where the users have a proactive role. Therefore, users have become the main providers and consumers of the available information. We believe that the new Internet paradigm is the mean that users want to use to carry out Group Decision Making processes. Some research in this area can be found in [8, 10].

Traditional Group Decision Making methods are designed for static decision making environments. This way, they assume that all the experts are available during the whole process and that no new ideas will appear during the experts debate. In practice, this situation rarely happens. Decision Making contexts dealt by these methods need to be more dynamic. Therefore, there is a need for traditional Group Decision Making processes to update and improve in order to work properly in this kind of dynamic environments. In a real Group Decision Making process, experts may not be available during the whole group decision making process because, for example, they may have to attend other appointments. Furthermore, it is possible that, at some point of the discussion, the experts consider necessary the opinion of an specific person. Also, it is possible that, during the conversation, they want to modify the alternatives set. This can occur, for example, if all the experts decide that an specific alternative is pointless or if a new idea comes to experts minds during the discussion.

The use of Group Decision Making methods for carrying out decisions implies that a computational system is being used as a mediator that takes care that the decision process is being carried out correctly. Making experts to deal with computational systems instead of other humans beings is quite a challenge [11]. It is necessary to develop techniques that ensure a comfortable communication between humans and the system.

In this paper, our purpose is to present the design of a Group Decision Making method that is able to work properly in changeable contexts. The designed method is able to connect experts independently of their location using Web 2.0 technologies. Furthermore, experts are allowed to abandon or propose new participants during the process. Moreover, experts can propose the deletion or addition of alternatives at any time. Three different preferences representation methods [12] and multi-granular fuzzy linguistic modelling methods [4, 13, 14] are used in order to allow experts to provide their preferences to the system in a comfortable way. Consensus measures [15, 16] are used to help experts to reach an agreement before making a final decision. Finally, proximity measures [17] are used to provide recommendations to the experts.

In section 2, basis of Group Decision Making models and preferences representation techniques are exposed. In section 3, the proposed Group Decision Making method design is described. Finally, in section 4, some conclusions are pointed out.

2 Preliminaries

This section presents some basis about multi-granular fuzzy linguistic modeling methods and group decision making problems. In subsection 2.1, basis of Group Decision Making models are exposed. Also, in subsection 2.2, the allowed types of preferences representation and the multi-granular fuzzy linguistic method used for allowing experts to choose the precision of their preferences are exposed.

2.1 Group Decision Making models

A Group Decision Making problem can be defined as follows [18]:

Definition 1. Let $E = \{e_1, \ldots, e_k, \ldots, e_m\}$ be a set of experts that have to make a decision. Let $X = \{x_1, \ldots, x_n\}$ a set of alternative that they have to rank. A Group Decision Making problem consists in carrying out the alternatives ranking using the set of preferences values $P(X)$ provided by the experts.

Generally, a typical Group Decision Making problem that uses consensus measures in order to assure a certain level of consensus before computing the final ranking is solved following the next process:

1. **Providing preferences step**: Experts provide their preferences to the system.
2. **Consensus process**: Consensus measures are used in order to determine the level of consensus. If the consensus is low, experts are invited to reconsider their position. Some guidelines can be provided in order to help them to reach an agreement. On the contrary, if the consensus is high enough, final decision results are computed.
3. **Aggregating information step**: Preferences provided by the experts are aggregated into a single collective value representing the overall opinion of all the experts.
4. **Selection process**: Using the collective value computed in the previous step, the final ranking of the alternatives is made. Since the decision has been made with a certain degree of consensus, the resulting ranking can be considered optimal. In this paper, the mean between the quantifier guided dominance degree (QGDD) and quantifier guided non-dominance degree (QGNDD) operators is used [17]. For each alternative x_i, they are calculated using the following expressions:

$$QGDD_i = \phi(c_{i1}, c_{i2}, \ldots, c_{i(i-1)}, c_{i(i+1)}, \ldots, c_{in}) \tag{1}$$

$$\begin{aligned} &QGNDD_i = \phi(c^s_{1i}, c^s_{2i}, \ldots, c^s_{(i-1)i}, c^s_{(i+1)i}, \ldots, c^s_{ni}) \\ &c^s_{ji} = \max\{c_{ji} - c_{ij}, 1\} \end{aligned} \tag{2}$$

where c is the collective preference relation matrix.

2.2 Preferences representation

In order for experts to provide their preferences in a comfortable way to the designed system, they are allowed to choose among a set of different preference representation methods and linguistic label sets. The three different representation methods that they can select among are exposed below [12]:

- **Preference orderings**: A preference ordering is defined as a set $O^k = \{o^k(1), \ldots, o^k(n)\}$ where $o^k(\cdot)$ is a function that carry out a permutation over the alternatives indexes $\{1, \ldots, n\}$. Therefore, each expert define their own ranking.
- **Utility functions**: An utility function is defined as a set $U^k = \{u^k_1, \ldots, u^k_n\}$ where $u^k \in [0, 1]$. This way, experts punctuate each of the alternatives.
- **Fuzzy preference relations**: They are defined as a matrix $P \subset X \times X$ where each value is represented by a membership function such as $\mu_{P^k} : X \times X \to [0, 1]$. $\mu_{P^k}(x_i, x_j) = p^k_{ij}$ indicates the preferences value of alternative x_i over x_j.

In order to carry out computations, it is necessary to express all the preferences using the same representation method. In [12], expressions to transform preference orderings and utility functions into fuzzy preferences relations are defined as follows:

- preferences orderings:

$$p_{ij} = f^1(o^k_i, o^k_j) = \Delta\left(\frac{1}{2}\left(1 + \frac{\Delta^{-1}(o^k_j) - \Delta^{-1}(o^k_i)}{n-1}\right)\right) \tag{3}$$

- utility functions:

$$p_{ij} = f^2(u^k_i, u^k_j) = \Delta\left(\frac{\Delta^{-1}(u^k_i)^2}{\Delta^{-1}(u^k_i)^2 + \Delta^{-1}(u^k_j)^2}\right) \tag{4}$$

In addition to selecting the preferences representation method, experts can choose the linguistic label set that better fit their necessities. Since experts have different knowledge about the dealt topic and they have different preferences, it is logical to let each expert to choose the linguistic label set that he/she prefers. Nevertheless, it is not possible to carry out computations directly over linguistic labels belonging to different linguistic label sets. For solving this issue, multi-granular linguistic modelling methods can be used. Thanks to them, it is possible to translate labels belonging to one linguistic label set into labels from another one.

A Group Decision Making method that uses multi-granular fuzzy linguistic modelling follows the next steps:

1. **Preferences providing step**: Experts provide their preferences using the linguistic label set that they prefer.
2. **Information uniformation step**: All the heterogeneous information provided by the experts are transformed into information belonging to an unique linguistic label set. After this transformation, computations can be carried out in a usual way.
3. **Group Decision Making process**: The Group Decision Making process is carried out as usual.

Due to its simplicity and effectiveness, the multi-granular linguistic modelling method exposed in [19] has been chosen. This method makes use of 2-tuple linguistic information [20] and linguistic hierarchies.

A linguistic hierarchy is defined as a set of levels where each one holds a linguistic label set with a different granularity. Each level is denoted as a tuple $l(t, n(t))$ where t indicates the number of the level of the hierarchy and $n(t)$ the linguistic label set granularity value representing the level. Higher levels stores linguistic label sets with high granularities while lower levels are assigned to linguistic label sets with low granularities. Therefore, a linguistic hierarchy is represented as the union of all its levels t as follows: $LH = \bigcup_t l(t, n(t))$. A linguistic 2-tuple is defined as a tuple (s, α) where s is a linguistic label and $\alpha \in [-0.5, 0.5)$ is a numerical value called the symbolic translation. If β is the aggregation result of the indexes of labels from a linguistic label set and $i = round(\beta)$, then the symbolic translation value can be obtained as $\alpha = \beta - i$. Therefore, α is the distance from the obtained numerical aggregation value to the closest label in the linguistic label set. Conversion of any aggregated numerical β into the tuple form (s, α) can be done using the next operator:

$$\begin{aligned} &\Delta : [0, g] \rightarrow S \times [-0.5, 0.5) \\ &\Delta(\beta) = (s_i, \alpha) \ with \begin{cases} s_i \\ \alpha = \beta - i \end{cases} \end{aligned} \tag{5}$$

where $i = round(\beta)$ and $\alpha \in [-0.5, 0.5)$. The reverse operation can be performed as follows:

$$\begin{aligned} &\Delta^{-1} : S \times [-0.5, 0.5) \rightarrow [0, g] \\ &\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta \end{aligned} \tag{6}$$

Using both tools exposed, linguistic hierarchies and 2-tuple representation methodology, the following multi-granular transformation function can be defined:

$$\begin{aligned} &TF_t^{t'} : l(t, n(t)) \rightarrow l(t', n(t')) \\ &TF_t^{t'}\left(s_i^{n(t)}, \alpha^{n(t)}\right) = \Delta\left(\frac{\Delta^{-1}\left(s_i^{n(t)}, \alpha^{n(t)}\right) \cdot (n(t') - 1)}{n(t) - 1}\right) \end{aligned} \tag{7}$$

Therefore, any of the labels belonging to each level t can be transformed into another label that belong to the linguistic label set from another level, t'.

3 Decision Support System workflow

In this section, how our designed group decision making method carries out a decision making process is showed. The steps followed by the system are exposed below:

1. **Initialization:** Variables needed to start the decision making process are set. First, the number of experts and their usernames are passwords are defined. Next, the initial set of alternatives is stored in the system. Finally, the values MAXWAIT and MAXROUND are fixed. MAXWAIT establishes the maximum amount of time that experts have to provide their preferences. Experts that do not provide their preferences in the specified amount of time are discarded from the decision making round. It should be pointed out that they can provide their preferences in the next round if they do it on time. MAXROUND establishes the number of round that experts have in order to reach an agreement. If the number of rounds indicated by the variable is reached, the final decision results are calculated. Notice that if MAXROUND is too high, the decision can last quite a long time to be reached. On the other hand, if MAXROUND value is too low, it is possible that the final decision results are not supported by a high percentage of the experts.
2. **Preferences providing step:** Once that the decision making initial parameters are set, the first round begins. Experts can log in into the system using their username and password and provide their preferences. For this purpose, they can choose the linguistic label set and preference representation method that they prefer.
3. **Uniforming preferences step:** The heterogeneous information provided by the experts is uniformed in order to allow the system to carry out operations with it. The uniforming process is carried out in two steps:
   (a) Preferences provided using preference orderings and utility functions are translated into the preference relation form using equations (3) and (4) respectively.
   (b) Labels belonging to different linguistic label sets are expressed using the same linguistic label set using the transformation function defined in (7).
4. **Computation of temporary Decision results:** Once that the experts preferences have been homogenized, preferences are aggregated into a single collective value and selection process is carried out. This way, experts can consult the temporary results and debate about them.
5. **Consensus measures calculation step:** Also using the homogenized version of the experts preferences, consensus measures are applied in order to calculate the consensus reached globally and for each alternative. This way, experts can know where there is more disagreement and focus the debate on the controversial points.
6. **Group Decision Making status control:** The system analyzes the global consensus value and the MAXROUND value in order to determine if another group decision making round is needed or not. If the actual number of rounds is higher than the MAXROUND value, the temporary decisions results calculated in step 4 are considered the final ones and the decision process is

ended. If the global consensus value is above a certain predefined threshold λ, then it is considered that experts have reach an agreement. Therefore, temporary decision results become the final ones and the process is ended. Otherwise, if the consensus value is not above λ and the number of round has not reach the MAXROUND value, the decision process continues to the next step.
7. **Generating recommendations:** Using proximity values [17], recommendations are generated for each expert. The objective of the recommendations is to assist experts and show them how to modify their preferences in order to increase the consensus of the overall process. It should be pointed out that experts are not forced to follow the recommendations.
8. **Go to step 2**.

An graphical scheme of this process can be seen in Figure 1.

Optionally, at any time during the group decision making process, expert can apply for the following processes to be started:

- **Alternatives changing request:** If one of the experts participating in the decision making process considers that the alternatives set must be modified, he/she indicates it to the system. When the system receives a changing alternatives request, it pauses the decision making process and notify all the experts about the requested change. All the experts must indicate if they agree or not with the change and, if a majority is reached, then the change requested by the users is performed. Otherwise, alternatives set is not changed. Finally, the decision making process continues as usual.
- **Experts changing request:** Two different requests related to the experts participating in the process can be performed:
  - *New expert request*: At any moment, during the decision making process, experts can suggest new experts to be added to the decision making process. If a new expert request is received in the system, the system pauses the decision making process and ask the experts if they want the new expert to be added to the system. Experts provide their opinions and, if a majority is reached, the new expert is added to the system and can participate in the actual decision making round and in the following ones.
  - *Rejection request*: If an expert is no longer available to attend the decision making process he/she indicates it to the system. The system revokes the granted permissions and delete his/her preferences from the decision process. This expert cannot access to the decision process until another expert asks for his/her inclusion in the system using a new expert request.

A graphical scheme of these two optional processes is shown in Figure 2.

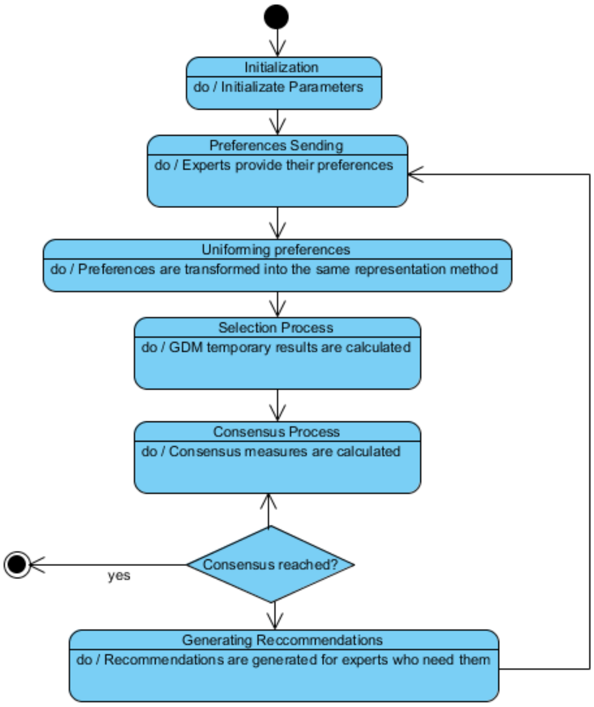

Fig. 1. Main workflow state diagram.

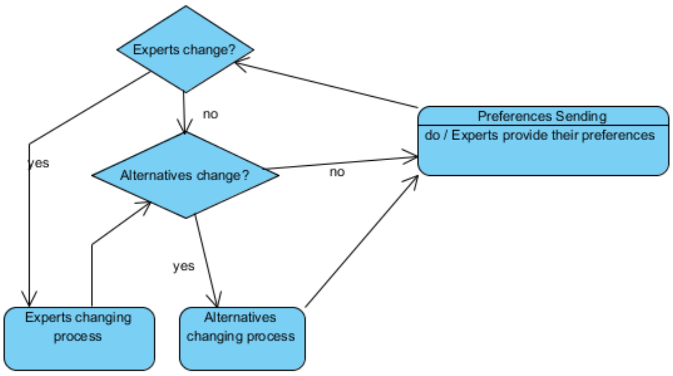

Fig. 2. Optional request workflow state diagram.

4 Conclusions

In this paper, a new group decision making support system that is able to deal with changeable contexts and work over the Internet using Web 2.0 technologies has been presented. The system presents the following three main advantages:

- **Experts do not have to reunite:** Experts can make decisions independently of their location using the Internet and Web 2.0 technologies. Thanks to this, experts do not have to reunite in order to carry out decisions. Therefore, they do not lose time in face meetings.
- **Userfriendly expert-system communication:** In order to ease the human-system communication, the system allows the users to express their preferences using different preferences representation methods and linguistic label sets. This way, each expert can select the way of expressing himself/herself that better fits his/her necessities.
- **Changeable Group Decision Making contexts allowed:** The designed group decision making support system is able to manage alternatives and experts sets changes during the decision making process. This way, if new ideas appear during the expert debate, the system can add them to the process. Also, if experts decide that one of the alternatives is not worth it for the discussion, that alternative can be deleted. Our system also allow experts to be added or removed from the decision process at any time. This way, if an expert has to leave the decision process in order to fulfill other responsibilities, he/she can indicate it to the system. Also, if experts consider, in the middle of the decision process, that a certain person opinion is worth it, they can add him/her to the system.

Although the presented method is still a design, we are planning to implement it and test it in the near future.

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