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Designing A Multi-Criteria Group Support System (MCGSS) Using Internet Technology

Sajjad Zahir and Brian Dobing
Faculty of Management, University of Lethbridge, Canada
Tel: (403) 329-2054, Tel: (403) 329-2492, Fax: (403) 329-2038, {zahir, brian.dobing}@uleth.ca

INTRODUCTION

Group Support Systems (GSS) offer potentially new ways for groups to work together, but most reported usage is still for systems that simply supplement face-to-face meetings. In a recent survey of GSS research (Fjermestad & Hiltz, 1998), the systems most frequently studied are quite unlike those needed by many organizations. Organizations are increasingly global and contain "virtual" components. Previous research has generally occurred in Decision Room environments using LANs, but the Internet enables the system to run asynchronously. However, only about 10% of research has studied asynchronous meetings. The GSS must support larger groups with global participations and richer inputs. But 80% of past research limited group size to 10 or fewer. The decisions they support are often complex, requiring many types of expertise and taking considerable time for deliberations. But over half of past studies were limited to one hour or less. Standard graphical interfaces that easier to use but most used older text-based models. Most groups studied had no leader or facilitator. Finally, most studies have used GSS that permitted only simple voting procedures (i.e., a majority rule) or none at all. (Some tasks involved allocation of funds to projects and thus permitted a limited form of proportional voting.) But these voting mechanisms are insufficient to adequately capture everyone's position with larger groups and complex issues.

Hammer (1990) argued that we need to re-engineer the workplace, not simply automate existing procedures. The same argument can be applied to the group decision-making processes. Early GSS were largely automation exercises, supporting brainstorming, facilitating anonymity, and compiling simple votes. Using Internet technology, a GSS can be designed to effectively handle larger groups working asynchronously. Such a system would offer considerably more value than most GSS studied so far by saving the costs and time of bringing people together.

Group leaders and facilitators need to know where members stand and, most critically, why. With face-to-face meetings, simple voting mechanisms are often sufficient. Participants likely know positions taken by most of their colleagues through their comments and body language. As the number of participants increases, their backgrounds become more diverse and they represent a wider range of locations and business functions. Obtaining a picture of where group members stand and how they might be clustered becomes more difficult. There is also an implicit assumption through much of the GSS literature that one-person, one-vote democracy is how organizations are run, or at least should be run. In practice, managers frequently seek input but do not feel bound by majority rule voting. Multicriteria voting improves the quality of input and helps managers with the more important tasks of analyzing alternatives and building consensus around the one chosen.

We have achieved this by building a Web-based multicriteria group support system that enables users to enter their intensity of preferences using a visual interface. The underlying decision model (Saaty, 1990) is the Analytic Hierarchy Process (AHP), widely used for modeling group decisions. Individual member's preference intensities are computed for decision alternatives after aggregating preference measurements with respect to their chosen criteria. Then, group preferences aggregated done either by arithmetic mean or geometric mean approaches (Forman & Peniwati, 1996). But the geometric-mean aggregation violates the Pareto optimality condition, an axiom of Social Choice Theory (Ramanathan & Ganesh, 1994). Zahir (1999 and references therein) extended the AHP to the Euclidean vector space (VAHP). He proposes a simple aggregation procedure (based on vector addition of preferences) that satisfies most Social Choice Theory axioms. The VAHP also enables us to compute group coherence in a straightforward manner. In this paper, we use the VAHP formalism for the sake of illustration, although the arithmetic mean method of aggregation within the traditional AHP group decision procedures could have been used without any loss of generality.

DESIGN OF THE MCGSS AND THE PROTOTYPE SYSTEM

A traditional Group Decision Support System (GDSS) (DeSanctis and Gallupe, 1989; Gray and Nunamaker, 1989; Sauter, 1997) integrates two concepts, Groupware and DSS. The Groupware component takes care of such functions as information exchange among the group members. The major DSS components of the MCGSS are Databases (DB), Model Bases (MB) and Dialogues. One table of the DB contains information about each decision-maker. Other tables contain the individual user's preference data used to calculate the group's aggregate preferences. The VAHP/AHP model component of the MB is accessed by decision-makers while entering their relative preferences for the criteria and the decision alternatives subject to each criterion. This computes the alternative preferences, aggregates them with the criteria weights, and finally calculates each member's overall preferences. The second component of MB consists of tools for group aggregation leading to the final intensity of preferences for the group. The system provides two dialogues, one for the group members and the other for the 'facilitator.'

One of the main interface design issues is determining the mechanism by which members express their judgments while comparing any two objects (i.e., criteria or alternatives). Within the framework of the AHP, the ratio scale takes values from 1 to 9 and their reciprocals (Saaty, 1990). The MCGSS expresses preferences using a new visual mode, a pair of side-by-side bars drawn in a graphical window whose heights are adjusted by dragging the mouse. The heights of the bars are measured in pixels and thus present an almost continuous variation. The ratio of the heights determines the relative importance of the two objects being compared. However, the minimum height cannot be zero as it will cause a division by zero; thus it is set as one pixel. We may also have situations where the value of the ratio exceeds 9. In that case, we assign a large value (H_o) to the ratio in order to reflect an overwhelming preference. The reciprocals are interpreted likewise.

The prototype system was tested using a Vending Machine decision scenario, a public policy issue relevant to the University community. A group of 10 students was formed as part of the experiment. The hierarchy of the decision process is shown in Figure 1. The decision makers had three alternatives, allow vending machines without controls (NoControlVM), allow vending machines but with controls on prices, locations, and items offered (ControlledVM), and prohibit vending machines (NoVM). The alternatives were compared on two criteria, Net Cost and Convenience. The system was developed as a Java applet and was posted (along with instructions) on the Web for

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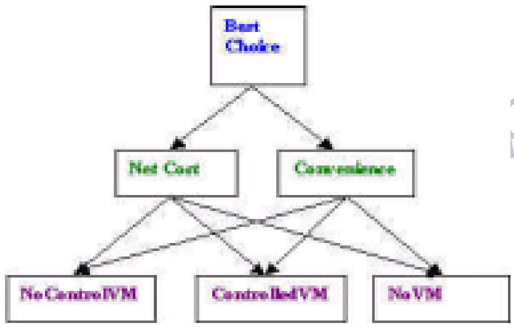
the group while completing the experiment. The members of the group exchanged information among themselves via e-mail. The author acted as the facilitator. ID numbers given to the members were needed by the system to forward data to the facilitator. Both the intensity based preferences and the direct voting responses were recorded for each participant.

Figure 1: Hierarchy of the decision scenario



The consistency index allows users to re-evaluate their pairwise comparisons. Each member of the group received an introduction to AHP and the system. However, in the prototype system, the set of criteria was the same for all in order to keep the system simple. For the same reason all user interactions were integrated into one screen. First, users had to pairwise compare the criteria (see Figure 2). Since there are only two criteria, only one comparison (hence two comparison bars) was needed. Then, under each criterion, three comparisons (involving three pairs of comparison bars) were needed. Finally, pressing the button 'Calc. Aggregate' produced the aggregate intensity of preferences in both numeric and graphical form. The 'Clear Plot' and 'Record Data' buttons erased the final output and sent the data to the facilitator for recording.

ANALYSIS OF THE DATA: COMPARISON WITH DIRECT VOTING

Table 1 shows the grand preference vectors of 10 participants in the group decision experiment. The indices 1, 2, 3 correspond to 'NoControlVM' (NC), 'ControlledVM' (CV), and 'NoVM' (NV) respectively. Then, the group aggregation rule (eq. (5) of Zahir (1999)) gives the normalized group preference vector $\hat{\mathbf{G}}$:

$$\hat{\mathbf{G}} = \begin{bmatrix} \hat{G}_1 \\ \hat{G}_2 \\ \hat{G}_3 \end{bmatrix} = \begin{bmatrix} .5717 \\ .6057 \\ .5534 \end{bmatrix}$$

We used MS Excel as one of the analysis tools in the MB. The intensities of preferences $\prod_i$ are calculated using (7) of Zahir (1999). They are

$$\Pi_1 = (\hat{G}_1)^2 = 0.3269, \quad \Pi_2 = (\hat{G}_2)^2 = 0.3669, \quad \Pi_3 = (\hat{G}_3)^2 = 0.3062$$

That means the relative priorities of the entire group as a whole are about 32% for NC, 37% for CV, and 30% for NV. On the other hand, if we count the votes, NC received 20%, CV received 80% and NV received 0% votes. The coherence of the group can be calculated using (8) of Zahir (1999) as follows:

$$r = \langle \mathbf{V}^i \cdot \mathbf{V}^j \rangle = \langle (\mathbf{V}^i)^T \mathbf{V}^j \rangle \quad (i,j = 1..\ 10,\ i \neq j) =$$

Figure 2: Section A—Decision forum © screen for AHP-based intensity of preferences

Table 1: Grand preference vectors of the group members ($V_1^2 + V_2^2 + V_3^2 = 1$) (see Zahir (1999) for definition of terms)

DM #	Vote	V1	V2	V3	DM #	Vote	V1	V2	V3
1	CV	0.5568	0.7348	0.3873	6	CV	0.4690	0.7141	0.5196
2	CV	0.5196	0.6782	0.5196	7	CV	0.4796	0.4583	0.7483
3	CV	0.3317	0.6557	0.6782	8	CV	0.5745	0.5916	0.5568
4	NC	0.9592	0.2000	0.2000	9	NC	0.6928	0.5657	0.4472
5	CV	0.5385	0.7000	0.4690	10	CV	0.3606	0.5099	0.7810

$$\frac{1}{45}\left(\mathbf{V}^1 \bullet \mathbf{V}^2 + \mathbf{V}^1 \bullet \mathbf{V}^3 + \ldots + \mathbf{V}^2 \bullet \mathbf{V}^3 + \cdots + \mathbf{V}^8 \bullet \mathbf{V}^{10} + \mathbf{V}^9 \bullet \mathbf{V}^{10}\right) = .9107$$

We used a module (part of the MB) written in C++ to compute the coherence. As expected, the experiment shows that intensity based procedures produces a 'softer' winning picture than the voting method. The MCGSS also provides information about the coherence of the group. Thus, it may be a better method for consensus building.

CONCLUSIONS AND FUTURE RESEARCH

The outline of the MCGSS conceptualised in this paper is preliminary in nature and further research is needed before a full-fledged version is developed. Once a system like this is made fully functional, we have to determine how acceptable such a system will be to corporate users.

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