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A Prototype of Multi-Objective Group Decision Support System with a Group Aggregation Method base

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Abstract

This study develops a framework of integrating multi-objective decision support systems (MODSS), expert systems (ES) and group decision support systems (GDSS) effectively to deal with multi-objective decision-making problems in a group under knowledge-based intelligent guide. The three dimensions, MODSS, ES, GDSS, are combined to overcome the limitations of each basic system and maximally enhance the competence of the integrated system. As part of this study, this paper proposes a two-level multi-objective based group decision systems framework and five group aggregation methods. A group subsystem is then developed to include the five aggregation methods in a method base. This makes the exploration of group satisfactory solution more flexible and effective.

Keywords

Decision support systems, group decision support systems, multiple objective decision-making, group decision making

INTRODUCTION

Research on theory and applications of multiple objective decision making (MODM) has been extensively conducted over the last three decades. Many decision support systems (DSS) based on multiple objective decision making (MODSS) have been developed (Korhonen 1991, 1992). However most of these research activities concentrated on MODSSs with respect to single decision maker. It's a fact that most of the organizational decisions are taken in a group environment and they involve multiple conflicting objectives. Literature, however, lacks in research and development of multiple objective based group decision support (MOGDSS). This paper presents a prototype of recently developed MOGDSS with intelligent front end.

The most important aspect of an MOGDSS is the aggregation of individual satisfactory solutions of each decision maker in an effective manner. In order to aggregate individual preferences in the solution, group aggregation methods are thus required. As different group aggregation methods are suitable for different types of group decision problems and group meetings, a group aggregation method base, which provides several different types of methods, is required. The method base can be used to support a wide range of group decision situations; help a decision group to be more productive and more effective; allow using multiple group decision methods for a group decision task; and find an appropriate method to solve each specific decision problem.

An integrated framework and prototype of intelligent multi-objective group decision support system (IMOGDSS) has been developed and related results have been reported in Lu, Quaddus & Williams (1999, 2000) and Lu (2000). The earlier publications have discussed the framework of IMOGDSS and implementation of a multi-objective decision-making (MODM) method base, and have shown that a knowledge-based MODSS is very useful to guide decision makers systematically towards the selection and application of decision methods. This paper focuses on the integration of MODSS and GDSS, specifically, the design and implementation of group aggregation (GA) method base. A two-level framework of multi-objective group decision making through imbedding a group component (subsystem) is proposed. The group subsystem is designed to include a group aggregation method base which has five group aggregation methods currently. These methods are used to aggregate individual solutions of multi-objective problems, which offers the 'most' compromise solution through either an interactive or non-interactive procedure.

After the introduction to the purpose of this study, section 2 describes the framework and prototype of IMOGDSS developed. Section 3 briefly summarizes goals of the group subsystem and the factors for performing a group aggregation. Section 4 describes a two-level framework of MODM-based group decision in IMOGDSS. Five group aggregation methods are briefly outlined in Section 5. Section 6 discusses the implementation and application of the group subsystem. The conclusions are presented in Section 7.

A FRAMEWORK AND PROTOTYPE OF IMOGDSS

IMOGDSS is implemented as an intelligence-based and GUI-based system that can work in an individual and group setting. IMOGDSS contains a sufficient number of MODM methods in its MODM method base, and provides a guide to select the most suitable method supported by a knowledge base, and has a group aggregation method base to aggregate individual decision maker's preference in order to produce the 'best' compromise solution. In a group meeting, each group member first receives a series of guidance to find a satisfactory solution using a suitable MODM method. These solutions then are aggregated into a compromise solution supported by the group aggregation method base. This compromise solution represents the preferences of the whole group, and the group as a whole thus expresses confidence in the compromise solution. Figure 1 shows the architecture of IMOGDSS prototype. It is observed that IMOGDSS is composed of many subsystems. This paper concentrates on the "Group subsystem" (shaded area) of Figure 1.

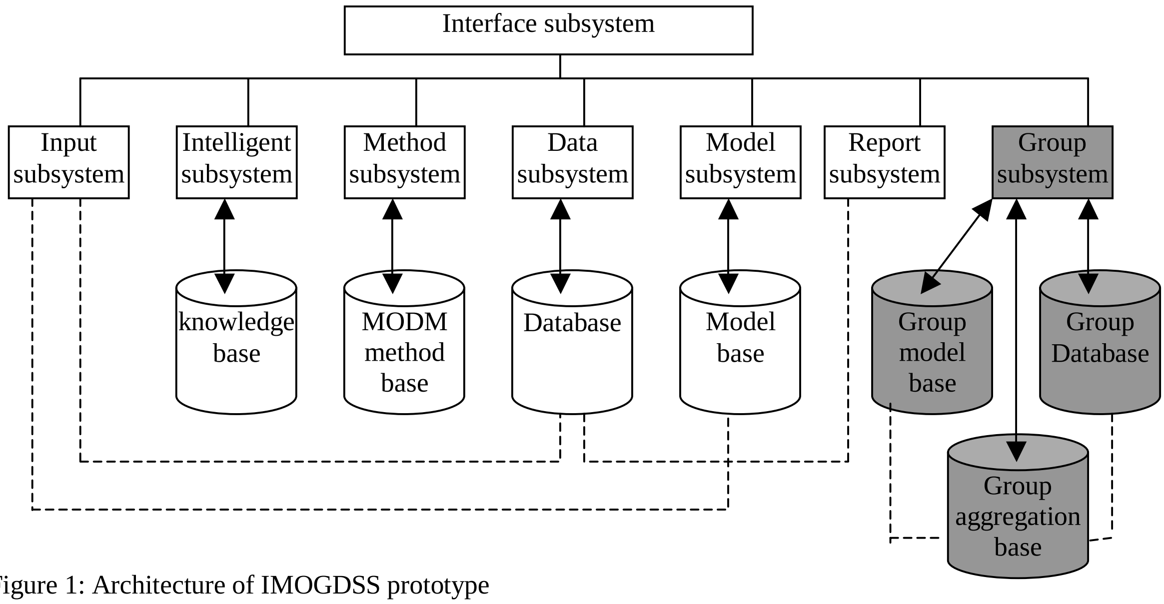

Figure 1: Architecture of IMOGDSS prototype

GOALS AND FACTORS OF MODM BASED GROUP AGGREGATION

Goals and Features of Group Aggregation

Systems that combine appropriate technologies, methodologies and facilities of decision support systems (DSS) and group decision making, creates the potential for providing enough flexibility to enhance the efficiency and effectiveness of group decision work. Such applications of information technology to support the decision work of groups have been referred to as GDSS (Gray 1987). Because decision making in a group occurs through interpersonal communication, the most fundamental goal of a GDSS is to support the exchange of ideas, opinions, and preferences within the decision group and to find a compromise solution for the decision problem (Gallupe, DeSanctis & Dickson 1988). MOGDSS is applied to solve an MODM problem in a group. Therefore, it must support the exchange of ideas about the multiple objectives with their goals and weights. It also must provide the possible solutions to individual preference. Finally, it must help the decision group find a compromise solution for the MODM problem through aggregating each individual solution.

In a typical MOGDSS, the tasks under 'idea generation' are to find and exchange solutions of MODM problems in IMOGDSS. Therefore, a basic goal of group aggregation (GA) in this study is to aggregate each group member's satisfactory solution which is generated by using a suitable MODM method in order to form a group solution. The group solution may be one of the individual satisfactory solutions or it may be a completely different solution. It all depends on which GA method is used. Another goal is to make an MOGDSS to suit with the broad characteristics of a group meeting. In an organization, decision groups often are geographically dispersed. Not all members will have the same information (information asymmetry). Often, group participants play a different weighted role for a decision solution. Finally, groups may or may not have a formally appointed leader (group leadership) (Barkhi et al. 1998). It has been found that any change in each of these characteristics will affect the performance of the group meeting (Barkhi et al. 1998). Also, some group aggregation methods are more suitable than others in the performance of a group, which posses some of the specific characteristics mentioned above.

The main feature of the group subsystem is the incorporation of a GA method base that will provide a number of group aggregation methods for the different situations of groups. This group subsystem is built on the MODM methodology subsystem of IMOGDSS. It works based on the individual solutions of the MODM problem produced by the group members. The GA method base will thus help to achieve more group effectiveness and achieve a more productive group.

Factors of Group Performance

The performance of group decision processes can be affected by five main factors: (1) participant information factor; (2) communication channel factor; (3) group leadership factor; (4) decision making time factor, and (5) decision making place factor. Each of them has two modes. For example, participants of the group may not have the same information (i.e., goals), because the group members may represent different business functional areas (e.g., marketing, production, purchasing). There are two communication channel modes: face-to-face (FTF) communication and computer mediated communication (CMC). FTF mode is only suitable in a decision meeting that is arranged at the same time and same place. CMC can be used for a decision meeting which is held at different time and in different places. CMC also may promote de-individuation by reducing the number of channels that are used for personal interaction. Leadership and its influence on small groups have been studied and leadership has not received wide attention in the GDSS literature (Barkhi et al. 1998). The leader (or leaders) acts as a cohesive force, helps achieve task-oriented goals, and improves the level of consensus by trying to be fair to every member. As a broad consideration, the role of the group members' feedback can also affect the result of decision meeting, for example some members' preferences can be taken as more important than others. For situations in which the knowledge necessary to solve a problem is distributed among different group members (Barkhi et al. 1998), the importance of the group members' preference, that is aggregated, should be allowed to be different.

FRAMEWORK OF MODM-BASED GROUP AGGREGATION

Two-Level Performance Framework

Maximization and satisfaction are two major frameworks of generic decision making (Kersten 1985). A combination of both may be used for MODM-based group aggregation. Each decision maker takes into account their preferences or wants to obtain the perceived optimal solution using the most suitable MODM method. They then submit their solutions and formulate the aspiration levels for each objective in a group, and a satisfactory compromise solution is then determined from among different solutions. IMOGDSS thus follows two levels to complete a group decision making for an MODM problem:

-Level 1: each group member finds a satisfactory solution for the MODM problem (supported by some MODM methods)

-Level 2: group members negotiate so as to achieve the 'best' compromise solution (supported by GA methods)

The issue of first level has been discussed in Lu, Quaddus & Williams (1999, 2000). This paper mainly describes the second level. In the second step, decision groups are formed to exchange information and ideas (solutions), and identify acceptable and desirable solutions. However, many times decision groups reach a dead end due to the differences among individual interpretations of the 'best' compromise solution. There is no rule for combining individual preferences into a group preference unless interpersonal comparison of 'utilities' is allowed. Consequently, most utility group aggregation methods require explicit interpersonal comparisons of utility and follow a normative approach assuming that a group decision rule can be constructed by aggregating the utility functions of group members (Iz & Jelassi 1990).

Individual solutions reflect different preferences of group members. Determining the best group solution requires the aggregation of individual preferences to find the 'best compromise' solution. A facilitator is needed at this level. He/she operates the group subsystem to import the members' solutions that are received by e-mail, discs or hard copies into the database of the group subsystem, and then operates one or more GA methods to arrive at the compromise solution. The facilitator has no influence on the final solution of a group. Figure 2 shows the two-level group decision structure.

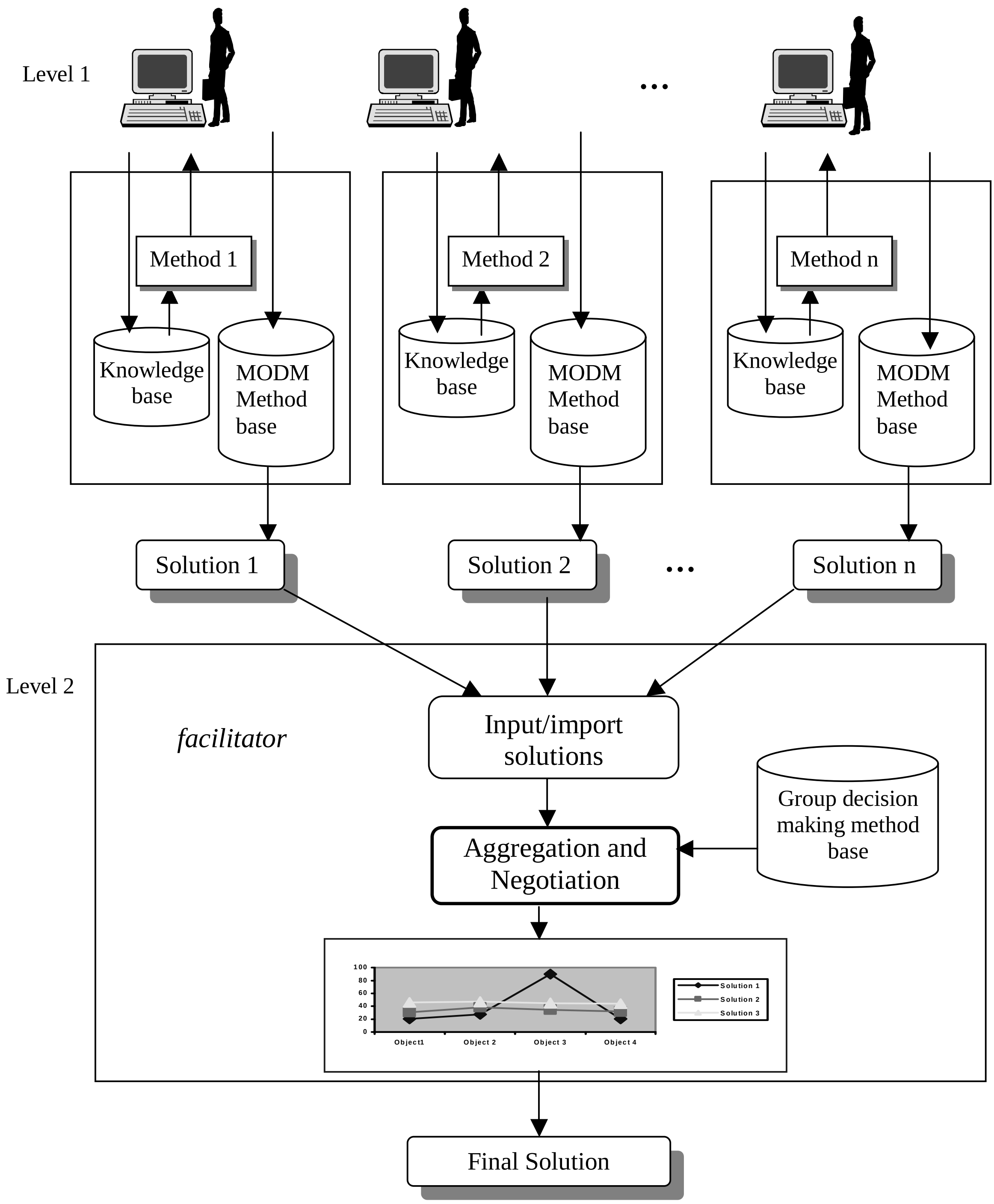

Figure 2: Two-level structure of group subsystem

Functional Integration of Group Aggregation method base

A new configuration of the group decision support software is needed to integrate a number of GA methods in a method base. There are five methods available in this GA method base: Average solution method (ASM), Weighting objective method (WOM), Weighting member method (WMM), Ideal solution method (ISM) and Solution analysis method (SAM). These methods are implemented as independent executables to facilitate the flexibility required of the system. These methods share similar data acquisition routines and these routines are developed as independent modules so that data acquired could be accessed by all the methods. As common data structure routines, two matrices, called '*Objective matrix*' and '*Variable matrix*', are generated through the input or the import subsystem, and are described in the common data structure routines.

There had been numerous GA methods proposed in the literature. However, they all work under a one-level framework where group members are allowed to provide their goals for each objectives and preferences at the beginning of or during the interactive decision process. In one-level framework, decision makers do not run different MODM methods to explore individual satisfactory solution. In the two-level framework, group members generate individual 'best' satisfactory solutions as alternatives, and then group aggregation process is invoked to find the 'best' compromise solution supported by the GA methods. The 'best' compromise solution can be one of the alternatives or it can be a new one, which is usually generated through a relaxation process.

Several methods in our GA method base (Table 1) use interactive process, which has a number of advantages:

- it intends to explores promising solutions rather than finding a 'best' solution;
- it interacts with each problem owner and thus reflects his/her preference structure;
- it evaluates the alternative solutions, thus becomes a learning process for the group members who understand a great deal about the aggregation process;
- it allows the group members to efficiently explain and clarify their preferences and allows different priority weights;
- it can avoid the decision groups reaching a dead-end due to the differences among individual interpretations of the 'best compromise' solution.

Some methods such as ASM are non-interactive, which has a number of advantages:

- it is easy to use in a 'group decision meeting' where members provide the individual solution at different times and different places;
- a compromise solution can be quickly reached;
- it can be first selected and used to obtain a preliminary group solution, and another interactive method can then be used to analyse this preliminary solution.

Type	ASM	WOM	WMM	ISM	SAM
Interactive		*	*		*
Non-interactive	*			*	

Table 1: Interactive or non-interactive characteristics of GA methods

GROUP AGGREGATION METHOD BASE

Following group aggregation (GA) methods are included in the GA method base. Each is described briefly.

Average Solution Method (ASM)

The average solution method is also called shortest average distance method. Lai, Liu & Hwang (1994) applied the principle of the shortest distance to propose an aggregation method with two distance criteria: ideal solution and worst solution. This principle is applied in this GA method with a single distance criterion: average solution. The aim of ASM is to obtain the 'most average' compromise solution from alternative solutions provided by the decision makers. An 'average value (AV)' vector called an average solution is generated based on group members' satisfactory solutions. In many cases, the average solution is not a feasible solution and so cannot be a compromise solution. This average solution is then compared with all alternatives. The closest (shortest distance from the average solution) one is recommended as the compromise solution.

Weighting Objective Method (WOM)

This method is also called weighted shortest average distance method. The method attempts to combine group members' preferences and the ranking for each objective into one relative average solution. The method focuses on aggregating the values of decision objectives in alternative solutions. Since the intensity of importance of each objective can be different in a decision problem, a weight matrix for the decision objectives is built and weighted distance is used in measuring distance between the solutions and average solution.

The algorithm is centered around a weight matrix W, whose elements represent the intensity of importance of objectives that decision makers prefer. Through this weight matrix, an average weight vector $\overline{W}$ is obtained and used to produce a set of weighted distances to the average solution from each solution. The 'weighted distance' between the average solution and each solution is compared and then a solution is selected which has shortest weighted distance. This compromise solution is therefore taken as a final solution if the group members are satisfied with it. Otherwise, the initial weights are modified by the decision makers and the above process is repeated. A set of new weighted distances are then obtained and a new compromise solution is determined. If this compromise solution is accepted, the process is terminated.

Weighting Member Method (WMM)

This method intends to combine group members' preferences and ranking of each group member into an average solution. The degree of importance of group members is often different. Particularly, when a group meeting has a leader, this leader's preference should reflect more to a final solution. Thus, a higher weight on the leader's solution is assigned than other members. In this case, the aggregation of alternative solutions not only involves the objectives, but also accounts for the group members' roles.

Ideal Solution Method (ISM)

Based on Lai, Liu & Hwang (1994), this method defines the distance between ideal solution and alternatives as a criterion to obtain the 'most optimal' compromise solution. The 'most optimal' solution is the one closest to the ideal solution, that is, it has the shortest distance from the ideal solution.

Solution Analysis Method (SAM)

This method is designed to use a relaxation process for objectives based on a preliminary solution (which can be produced by ISM or other method). The aim of this method is to provide more interaction and negotiation for group members. Figure 3 shows the process of group analysis and aggregation for SAM.

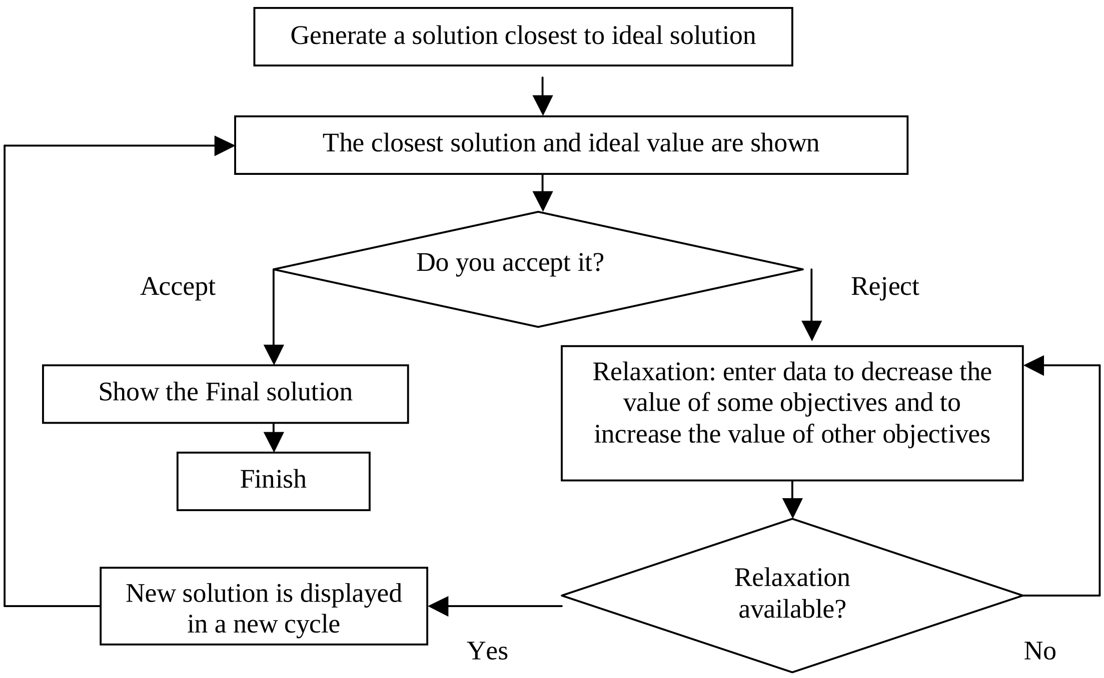

Figure 3: Solution Analysis Method (SAM)

IMPLEMENTATION AND APPLICATION OF GROUP SUBSYSTEM

The group subsystem is one of eight subsystems of IMOGDSS (see Figure 1). The subsystem is used in a group environment where group members' solutions need to be aggregated so as to achieve the 'best' compromise decision. The group subsystem is activated by invoking the '*group*' menu on the main menu screen of IMOGDSS (Lu 2000), as shown in Figure 4.

All group members' solutions, average solution and ideal solution can be shown in a chart in order to view and understand the distances between average (or ideal) solution and decision makers' solutions. Figure 5 shows a graphical display of three alternatives and an average solution.

This subsystem will support to produce the 'best' compromise solution in different kinds of meetings. Table 2 shows the application of various GA methods in various types of meetings. The set of GA methods has different advantages and can be used in a flexible way through various possible combinations of them. In an interactive method, group members need to define clearly and input their weights for objectives or members, or make a solution analysis through a relaxation process. While in a non-interactive process, a final solution is displayed immediately once the group members' solutions are imported. A mixed process is recommended, where a non-interactive method is first used to produce a preliminary compromise solution, then an interactive method can be used to improve the solution until the best compromise solution is found.

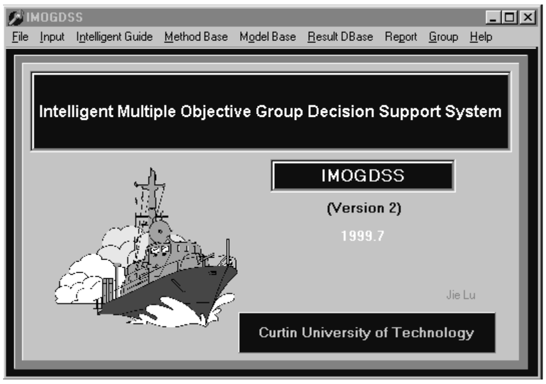

Figure 4: System desktop of IMOGDSS

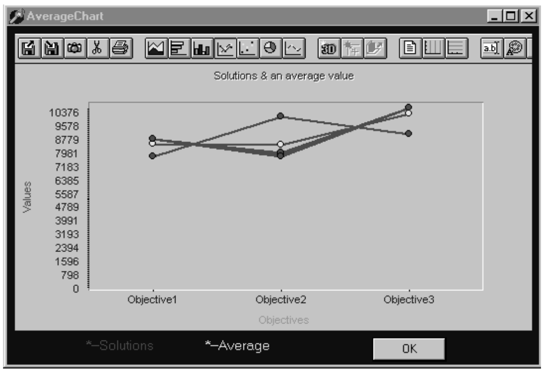

Figure 5: A Graphical display for a group of solutions with an average solution

Suitable	Same data	Different data	FTF	CMC	Leader	No Leader	Same time	Differ ent time	Same place	Differ ent place
ASM	*	*	*	*		*	*	*	*	*
WOM	*	*	*		*	*	*		*	*
WMM	*	*	*		*	*	*		*	
ISM	*	*	*	*		*	*	*	*	*
SAM	*		*			*	*		*	

Table 2**:** Relationships between the five methods and five factors

CONCLUSIONS

This paper presents the framework and prototype of two level MODM-based group decision systems. A group subsystem is developed to include a GA method base with five methods. This system allows group members to offer their satisfactory solutions as alternatives, and supports a decision making group to obtain the 'best' compromise solution. These alternative solutions involve multiple conflicting objectives and are provided respectively by multiple members who may have different business functions and preferences. This group subsystem has three main advantages. First, it provides a GA method base to allow the use of multiple group decision methods in a wide range of group decision situations, such as: allowing group members to work in a face-to-face or dispersed environment, which is also suitable for groups with or without leadership. Second, it works under a two-level group decision-making framework, where each individual group member first finds a suitable MODM method and gets individual satisfactory solutions. The satisfactory solutions are believed to maximally reflect group members' goals and preference. Thirdly, it supports a decision group to choose an appropriate GA method to solve each specific decision problem, which then helps the group to be more productive and more effective. Our immediate goal is to extend the IMOGDSS for e-decision support in group environment via internet.

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