A Group Decision Support System by Externalizing, Sharing and Reflecting Individual Viewpoints

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November, 12 1996
IS-RR-96-0031

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ISSN 0918-7553

ABSTRACT This paper proposes a group decision support method which can analyze participants' individual different viewpoints on their cooperative problem solving. The problem solving is usually complicated because each participant has his individual viewpoints based on his own sense of values. In our method, first, a thinking support method is used to analyze primary factors of a decision problem and to construct a hierarchical evaluation structure of the problem. Secondly, AHP(Analytic Hierarchy Process) is used to evaluate each participant's subjective judgements quantitatively based on the derived structure. In addition, we design a tradeoff analysis support function which applies a sensitivity analysis method to make a consensus formation effectively. Unlike conventional methods using AHP, our method is more analytical and focuses importance on supporting consensus making process. In this paper, we describe the outline of our method and then show an implementation example which works on network environment. The experimental result and system evaluation are also given.

KEY WORDS Decision-making, CSCW, Analytic Hierarchy Process

1. INTRODUCTION

The study of groupware or CSCW which aims to support intellectual collaborative work has been extensively advanced in recent years. By development of information network techniques or the distributed processing techniques, studies on a group decision support system enhance their value as groupware applications. Group decision-making can be achieved by consensus making which is obtained by the communication among the group. A system to support this process with the computer is known as a group decision support system (GDSS:Group Decision Support System)(Gray,1987).

To solve a decision-making problem effectively, it is necessary to externalize, share and reflect participants' individual viewpoints based on their sense of values. According to this, it is important that all participants can grasp the situation where each viewpoint of the participants is and moreover how much it is important. Therefore, we think that consensus making can be advanced by adjusting individual viewpoints each other and by repeating the process of compromise or self-assertion.

In a consensus making process of group decision-making, the participants' individual viewpoints and preferences are generally different with each other because they have their own different senses of value. As the result, a conflict occurs among the participants. When one tries to cancel this conflict, a competition condition will occurs. We defined tradeoff as a relation that we cannot help making some purposes sacrifice to have priority over the other purposes under such a situation. To achieve the consensus making among all participants, it becomes necessary to analyze this tradeoff relation and the process of canceling a mutual conflict.

This paper deals with an alternative choice-type group decision-making problem. Then, we describe a group decision-making support method which reflects individual viewpoints to the analysis for the consensus making and has a tradeoff analysis function for conflict cancellation. The outline and the evaluation experiment example of our system which has been developed based on this method are also described.

2. THE PROPOSED GROUP DECISION SUPPORT METHOD

An alternative choice-type group decision-making support process in this study is composed of the following three parts as shown in Figure 1: (1) construction support of an evaluation structure, (2) alternative evaluation support based on the evaluation structure and (3) consensus making support among the participants. The detail of each part is described as follows.

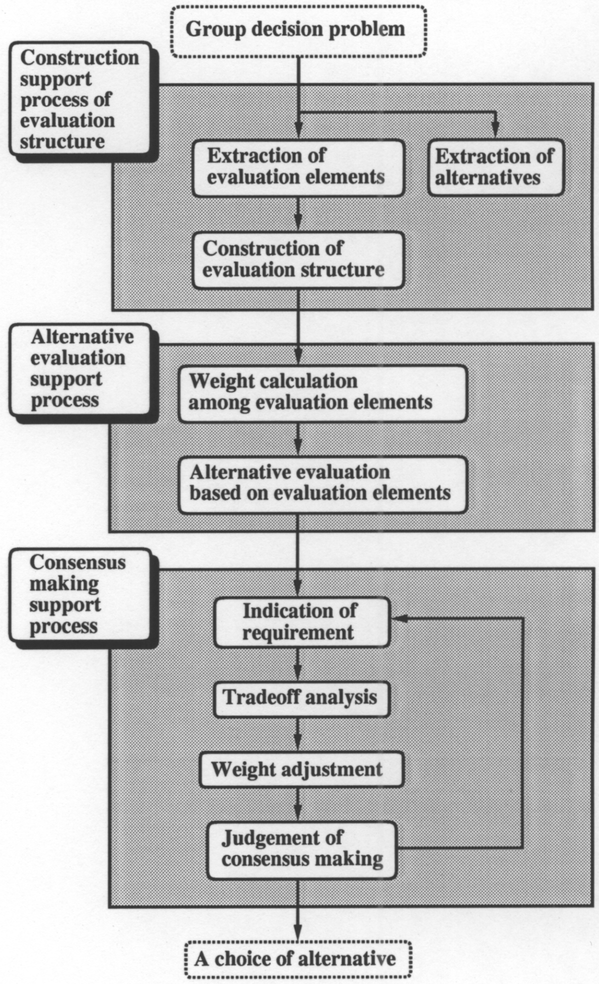

Figure 1 The proposed group decision support process model

2.1. Construction support of evaluation structure

An evaluation structure should be constructed hierarchically and visually to extract the evaluation elements which are necessary to solve a decision-making problem and to make relations between each evaluation element clear. In this process, all participants must have a common recognition to the decision-making problem. Moreover, the evaluation structure which they consent to must be effectively constructed. At this point, we use a thinking support method by the group, named KJ method(Kawakita,1975) which is widely used in Japan. ISM(Interpretive Structural Modeling)(Warfield,1974) can also be used for the same purpose. First, we decide participants who discuss a decision-making problem and allow them to do the following three tasks.

- Extraction of alternatives which become candidates of the solution.
- Extraction of evaluation elements set for the alternatives choice.
- Construction of an evaluation structure composed of the evaluation elements.

2.2. Alternative evaluation support based on the evaluation structure

Generally, the evaluation elements which compose an evaluation structure often differ with each other in their measure respectively and they have some subjective characteristics. Then, the participants' viewpoints are directly reflected in preference order by comparisons among these evaluation elements. Therefore, we try to show differences of each participant's viewpoints by quantizing these preference order. One of quantizing methods is a conventional multi-attribute utility theory. This is a method of expressing a preference structure of a human by a mathematics model. However, this method needs to construct an appropriate preference structure by measurement of utility functions and this task needs heavy loads. At this point, we try to quantize an alternative evaluation based on the evaluation structure using AHP (Analytic Hierarchy Process)(Saaty,1980) which has the following characteristics and combines subjective evaluation with a systems approach.

- Easiness of subjective evaluation among evaluation elements with pairwise comparison.
- Easiness of quantitative evaluation among evaluation elements which have a different measure.
- Existence of an index which shows consistency of the evaluation.

AHP is a method of calculating ratio measure values with the consistency from doing each pairwise comparison among the elements and the values, assumed to be relative weights, denote the priority. As the weight, AHP defines the eigen vector $\omega = (\omega_1, \omega_2, ..., \omega_n)$ of the maximum eigen value λ_{max} obtained from the pairwise comparison matrix A in Formula(1).

$$A = [a_{ij}] \quad (1)$$

where a_{ij} is a pairwise comparison value

$$a_{ii} = 1,\ a_{ji} = 1/a_{ij},\ a_{ij} > 0 \ \ (1 \leq i \leq n,\ 1 \leq j \leq n) \quad (2)$$

A relation between a_{ij} and ω is shown by Formula (3) when the consistency of the pairwise comparison matrix is complete.

$$a_{ij} = \omega_i/\omega_j \quad (3)$$

However, the consistency is generally incomplete because a pairwise comparison value is subjectively judged and fixed. According to the theory of AHP, the degree of consistency is called consistency index and is shown using symbol C.I.. C.I. is given by the following Formula (4).

$$C.I. = (\lambda_{max} - n)/(n-1) \quad (4)$$

We apply such a computation procedure on the evaluation element group of all levels of the evaluation structure and among the alternatives. The total weight to each alternative $s_j(j = 1, .., m)$ can be calculated by Formura (5).

$$s_j = \sum_{i=1}^{n} \omega_i v_{ij} \tag{5}$$

where, $v_{ij}$is the weight of the alternative j for evaluation element i.

In case of group AHP, a weight of a group is defined by the arithmetic mean of each member's weight conventionally. But in the case that quite defferent opinion group exists or members' opinions are too different in the group, we cannot define the arithmetic mean as the group weight. To solve this problem, we propose that the consensus making support described in the next subsection is needed.

Incidentally, to improve operate-ability and practicality, we have implemented the following three methods in our system.

- *Incomplete pairwise comparison method in AHP*
  This is a method(Harker,1987) composing the total pairwise comparison matrix which has a consistency as a whole by complementing the part for there to be a consistency in which there is not confidence in a pairwise comparison or not to be understood by the information lack. There is an effect that the number of the pairwise comparison decreases by using this technique. And this effect can also diminish the load of the pairwise comparison work when the number of the comparative elements is increased.

- *The pairwise comparison correction method for the consistency index improvement*
  When the value of consistency index is bad, we can revise the value of the pairwise comparison which should improve the consistency by this method(Shintani,1992).

- *The tradeoff analysis by the sensitivity analysis*
  When there is a difference between the expectation (or dissatisfaction) and the weight values obtained by AHP, it is necessary to revise the weight values. Also, in the next step of consensus making, the weight values must be adjusted to advance the compromise process of the mutual requirement. To achieve the above purpose, tradeoff analysis among the participants becomes necessary. We propose an efficient technique of tradeoff analysis. Our approach(nkato,1995) applies the sensitivity coefficients of weight vector ω(the values calculated by differentiating the weight vector ω by the pairwise comparison value a_{ij})(Masuda,1987). By this method, we can support the strategies which revise any pairwise comparison value by referring to these calculated sensitivity coefficients. More precisely, we can choose the combination of the pairwise comparison that makes the tradeoff operation work with the most effectiveness. By showing a user the candidates a_{ij} orderly with respect to the sensitivity coefficient, the user can revise the pairwise comparison value a_{ij} which bring about high tradeoff effect. (i.e., the sensitivity coefficient is high.) Repetitively, the weight is re-calculated and the consistency index will be checked again.

2.3. Consensus making support among the participants

Here, we define the weight distribution of the evaluation elements obtained by AHP as the viewpoints of each participant. At this point, the weights of the evaluation element group which are placed in the top level of the evaluation structure show the macro viewpoints of the participant. We can take the strategy that tries a consensus making by choosing the evaluation element in order and extracting some conflict parts with the other and adjusting the weights by repeating tradeoff analysis. Here, as the tradeoff analysis method, we use sensitivity analysis method which is effective for actual consensus making.

The procedure of weight adjustment with a person who tries to make a consensus is simply shown below. Hereafter, we call this person an opponent. First, one's requirement to increase or decrease the evaluation value of an alternative which the opponent decided is given to our system. The system searches for a combination set of the pairwise comparison of evaluation element which the opponent should change to reflect one's requirement by tradeoff analysis function. Then, the system shows them to the opponent in the list form in order which one's requirement reflection effect is high. Next, the opponent makes reference to the list and chooses a combination of pairwise comparison which he can compromise and adjusts its pairwise comparison value. With this adjustment, the opponent's evaluation value is adjusted to the direction which goes along one's requirement. In the same timing, both show their requirements and adjust their own evaluation value in the range which can compromise to each other. By repeating the above procedure, we attempt to support a consensus making process. The detail procedure is as follows.

- *Procedure 1 Indication of requirements*
  At first, the participant chooses the opponent who shows a requirement. Next, they choose an evaluation element of the top level of the evaluation structure and then analyze some conflict parts between them in the lower hierarchy level and the participant shows his requirements to the opponent. Concretely, he can require the opponent to raise or lower the opponent's weights of the alternatives to cancel the conflict.

- *Procedure 2 Sensitivity analysis of requirements*
  Using the sensitivity coefficient of the weights, our system calculates values by Formula (6) in combination of all evaluation elements in the hierarchy structure. After this, the system shows the set of the pairwise comparisons which becomes candidacy to adjust in order of R_{ij}, for instance, in order of the effect which can step up to the opponent's requirement.

$$R_{ij} = t_N \omega_{ij} S r \qquad (6)$$

  where, t_N is a weight value of evaluation element N, ω_{ij} is a sensitivity coefficient vector which denotes the changing weight values by changing the pair comparison value a_{ij}. S is a matrix whose arrays are weight vectors of the alternatives calculated by weights of evaluation elements which are subordinate to N. r is a vector which denotes the changing directions of the requirements for the opponent's weights of the alternatives. (i.e. 1 : The requirement which raises the weight of the alternative, 0 : No requirement, -1 : The requirement which lowers the weight of the alternative)

- *Procedure 3 weight adjustment*
  Each participant adjusts a pair comparison value while referring the adjustment candidacy list of pair comparison obtained by procedure 2. Using the tradeoff analysis function as necessary, the degrees of weight adjustment can be considered. A adjustment result can be displayed in all windows of all participant's terminals at once. Referring to the result adjusted by the opponents, each participant can adjust his own evaluaiotn if necessary. In such a way, a consensus making process can be advanced.

3. IMPLEMENTATION EXAMPLE

As the characteristic of the group decision-making process, the movement of the intention of the whole group as well as the individuals changes gradually according to the situation. In other words,

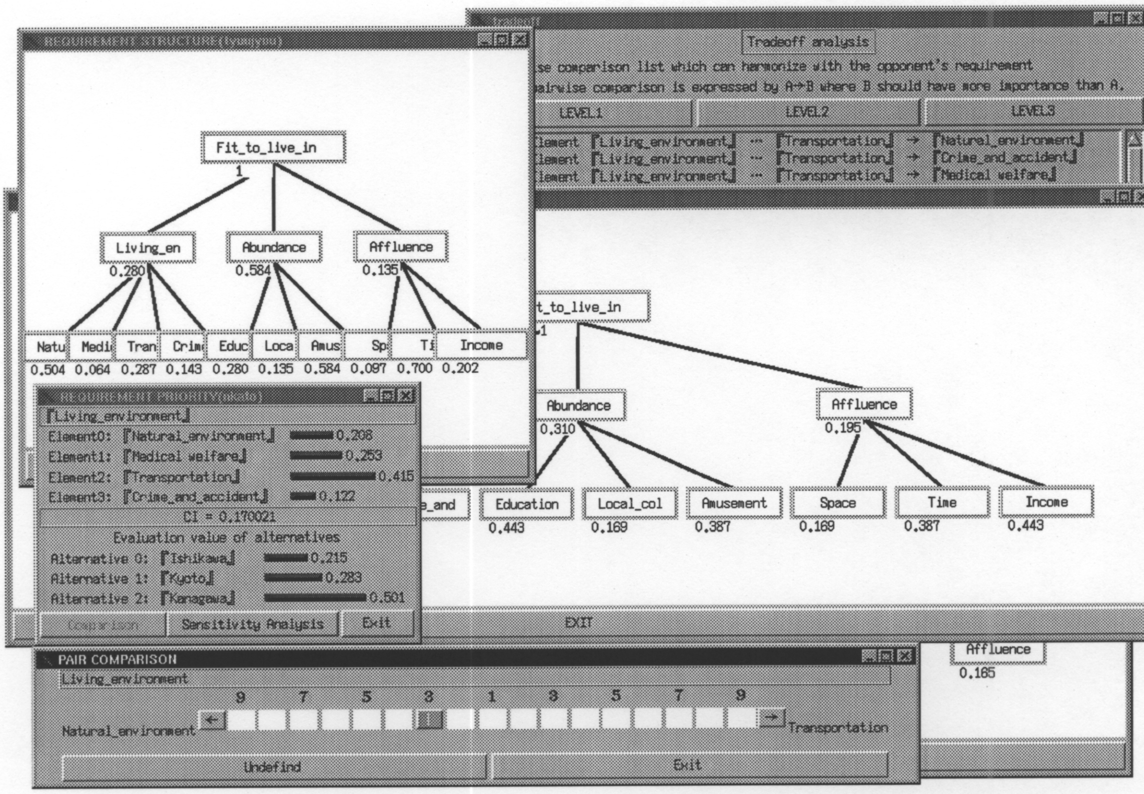

Figure 2 An example of operation windows

the interaction by the communication among the participants influences a decision-making result directly. From this point, it is important to support the flow of the whole decision-making process smoothly. We devise that the above-mentioned group decision-making support process can be executed smoothly on the computer network. So, we attach great importance to the implementation of WYSIWIS(What You See Is What I See) and chat function including GUI.

We are now implementing a prototype system on a SUN work station with X window system environment. The system incorporates a thinking support system D-ABDUCTOR(Sugiyama,1992) for construction support of evaluation structure. By using this system, it can be expected that we can improve common consciousness for the problem solving more than the conventional way and the construction of the evaluation structure becomes more accurate. Also, it can be expected to obtain AHP evaluation which will be more stable in the individual participants.

An example of our system's operation windows in the consensus making process is shown in Figure 2. We can execute this system with interactive multi-window system and all users can see the same screen. In Figure 2, the screen center window behind shows one's evaluation structure, the upper left window shows the opponent's evaluation structure and

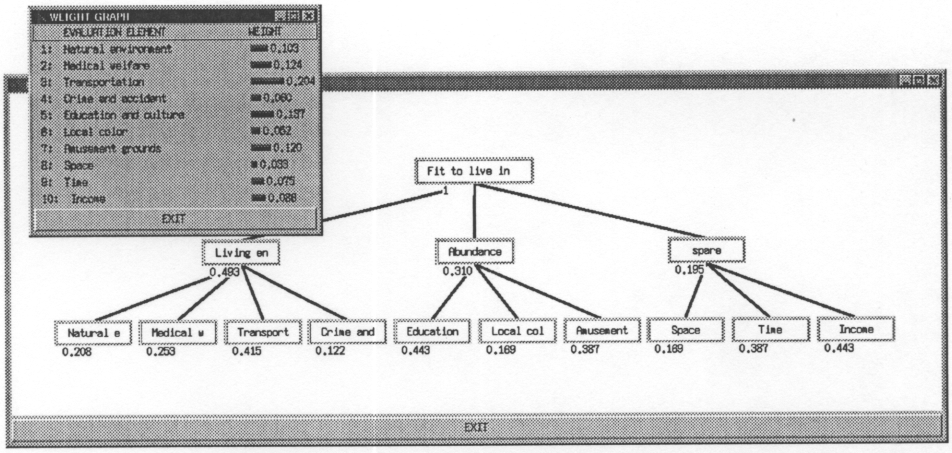

Figure 3 An example of evaluation structure

the lower right window shows their average respectively. Also the upper right window shows the result of tradeoff analysis by sensitivity analysis. Moreover the lower left window shows the evaluation value of the alternatives by the partial evaluation structure. The lowest window is an input screen with pair comparison value between two evaluation elements. The result of adjustment can be reflected in all windows of all participants' terminals.

4. EVALUATION EXPERIMENT

We experimented the evaluation test "it is fit to live in" which is an administrative problem in each of the administratives division of Japan. The test subjects are four in amount, two sets. First, the evaluation structure obtained by our system is shown in Figure 3. Each value of weight is denoted at the lower left side of its own evaluation element box in the structure. Next, the comparative experiment result of the consensus making among two persons who use or not use the tradeoff analysis support function by our system is shown in Figure 4. The broken line shows the fluctuation of the vectors distance (the vertical axis) for the alternatives weights between two test subjects in each time of changing their weights. Also, the solid line shows the fluctuation when using this tradeoff support function.

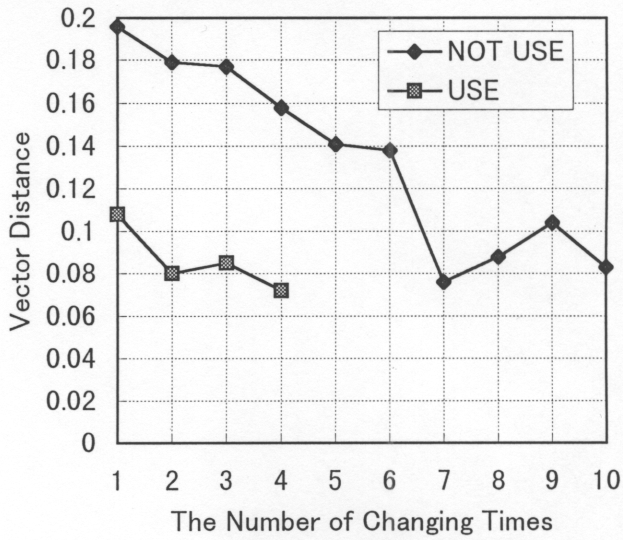

Figure 4 An result of the experiment

When using a tradeoff support function by the sensitivity analysis from the experiment result, the number of changing times for the weight decreased below the half compared with the case not to have used this function. From this result, we find out that it is easy to find the pairwise comparison set which should be adjusted in order to harmonize with the opponent's requirements and the adjustment of requirements among the test subjects could be easily judged based on pairwise comparison level.

5. CONCLUSIONS

We have proposed a new method of group decision-making support for selecting alternatives and have described an implementation example and an evaluation experiment example. A characteristic of our method is to externalize, share and reflect individual viewpoints for a group decision-making process. Our method can deal with the computer supported cooperative work such as group decision-making among the perticipants who have different senses of value with each other.

Characteristics of our system is as follows. First, it is possible to analyze and evaluate more partially and more synthetically to have considered the participant's individual viewpoints with WYSIWIS function compared with the conventional group decision-making support system using AHP method.

Secondly, our system attaches great importance to the support of the consensus making process. That is, it has a tradeoff analysis support function by the sensitivity analysis for compromise and conflict cancellation.

Lastly, it is a group decision-making support system which combines construction of the evaluation structure by thinking support method with evaluation of the subjective judgements based on the structure by AHP method.

Through an experiment example for decision-making, the number of times of changing the weight for the conflict cancellation decreased when using the tradeoff analysis support function, and the improvement of the consensus making support effect was found.

REFERENCES

Gray(1987)Group Decision Support System: Decision Support Systems, 3, 233-242.

Harker,P.T.(1987)Incomplete Pairwise Comparisons Method in The Analytic Hierarchy Process: Math. Modeling, 9, 353-360.

N.Kato and S.Kunifuji(1995)A Study of Function Analysis Support Reflecting User's Requirement for Software Development: Information Processing Society of Japan SIG Notes 95-GW-9, 63-68(in Japanese).

J.Kawakita(1975)The KJ Method : A scientific approach to problem solving: Kawakita Research Institute.

T.Masuda(1987)Sensitivity Coefficients of Consistency Index and Priorities Used in the Analytic Hierarchy Process: The Transactions of The Institute of Electronics, Information, Communication Engineers, A Vol.J70-A, No.11, 1562-1567 (in Japanese).

Saaty,T.L.(1980)The Analytic Hierarchy Process: McGraw-Hill.

T.Shintani(1992)Implementing a rule based decision support mechanism for selecting alternatives: Journal of Japan Society for Artificial Intelligence, Vol.7, No.3, 463-474 (in Japanese).

K.Sugiyama and Misue(1991)Visualization of Structural Information; Automatic Drawing of Compound Digraphs: IEEE Trans. of SMC, Vol.21, No.4, 876-892.

Warfield,J.N.(1974)Developing Interconnection Matrices in Structural Modeling: IEEE Trans. of SMC, Vol.SMC-4, No.1.