Group Decision Support Systems for Creative Problem Solving

Susumu Kunifuji†, Haruyasu Ueda, Takayuki Tamura, Naotaka Kato, and Hideki Nagata
† Japan Advanced Institute of Science and Technology, Hokuriku
(e-mail:kuni@jaist.ac.jp)

Abstract

This paper presents our research and development of group DSSs(Decision Support Systems) for creative problem solving. Our systems depend on KJ(Kawakita Jiro) method[1,2] and QDA(Quality Deployment Approach) method[3,4].

First, we show you our motivation and philosophy on creative problem solving. Second, we give you a short presentation to our past abduction research. Our concern is "How to break the barrier of AI approach". In the same chapter, we present a new type of DSS GRAPE (GRoupware for Acquiring, Processing, and Evaluating knowledge) [5,6] for the classification-choice problem. GRAPE is a knowledge acquisition support groupware and a bottom-up type group DSS. From the experince of developing GRAPE, we recieved a lot of new ideas for building creative DSS. They include QDA-based DSS[7,8], KT(Kepner · Tregoe) method based system[9], etc. Lastly, we state a tentative conclusion of building a hybrid system with both divergent thinking support functions and convergent thinking support functions.

1 Introduction

We currently focuses researches on the integrated architecture of knowledge acquisition and learning, groupware, and creative thinking support systems. Combining an appropriate system analysis methodology united with a system modelling methodology (i.e. ISM (Interpretive Structural Modeling)[10,11], Extended ISM[12], Fuzzy Clustering[13,14], and AHP (Analytic Hierarchy Process)[15], etc.), we designed and implemented a knowledge acquisition support groupware GRAPE. GRAPE is a bottom-up type group decision support system. From the experience of developing GRAPE, we received a lot of new ideas for building a group decision support system.

Otherwise, there are several manual methods for creative thinking such as KJ(Kawakita Jiro) method[1,2], NM (Nakayama Masakazu) method[16], and Equivalent Transformation Theory by Kikuya Ichikawa[17] in Japan. They are methods for getting new ideas from given data. Inspired by these methods, we are now designing and implementing a new type of creative group decision support system for research and development management, that is, a hybrid system with divergent thinking support functions and convergent thinking support functions.

This paper proposes new type of QDA(Quality Deployment Approach)[3,4] based group DSSs, which are DSSs that enforce the decision maker to judge with rationality. Each system is respectively a succesor of GRAPE. That means they are bottom-up type group decision systems with convergent thinking support functions.

2 KJ-method and Creative Problem Solving

Generally speaking, the Japanese said to be lack of big creativity talent, for example, the number of the Nobel prize. As the reflection of this observation, the Japanese has a lot of creative thinking support manual methods to support their intellectual activities for research and development management, requirement analysis, total quality control, and creative problem solving,

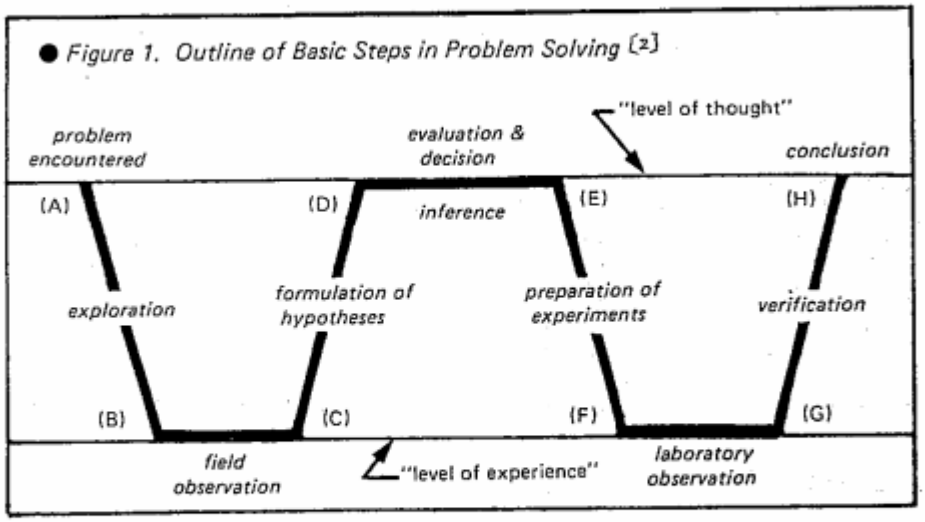
They are KJ method invented by Kawakita Jiro, NM method by Nakayama Masakazu, Equivalent Tranformation Theory by Ichikawa Kikuya, and DTCN method by Esaki Michihiko[18], etc.

Fortunately, when the first author was a student of Tokyo Institute of Technology, he had a nice training on creative solving from Prof. Jiro Kawakita, himself. Also, he had been a chief researcher of ICOT, Japanese Fifth Generation Project, and researched and developed such AI systems as (1) KAISER(Knowledge Acquisition oriented Information SuppliER)[19] and (2)HRS(Hypothetical Reasoning System)[20]. Then, he is a researcher of both the KJ people and the AI people. Accordingly, we are investigating KJ method based group DSS united with a system modelling technology, AI technology, and GW technology.

Anyway, at the first, we would like to explain the KJ's problem solving methodology. He explains, in Fig. 1 of the paper[2], that any human problem solving process consists of the following steps.

"In a scientific inquiry, one encounters a problem at point A on the thought level. As the first step in solving this problem, he proceeds to explore the situation surrounding the problem between points A and B, and next to collectall relevant and accurate data through field observation between ponts B and C. Given this data, he next formulates or develops a number of hypotheses between points C and D. Having returned to the thoght level, at point D, he next evaluates his hypothses and decides which to adopt. Between points D and E, he infers and revises the adopted hypothsis through deductive reasoning. Next, he devises an experiment for testing the adopted hypothesis between points E and F,

and ovserves the experiment between points F and G. Given the results of the experiments, he can verify his hypothesis between points G and H, and finally arrive at a correct conclusion at point H."[2]



Note that the same idea had beeen proposed from C. S. Peiece. It is called that the steps from A to D is an abduction process, the steps from D to E is a deduction process, and the steps from E to H is an induction process. If we looked at the KJ method from another angle, it consists of the next steps in the following: (1)Presenting the problem: (2)Understanding the existing state of things related to the problem; (3)Hypotheses formation; (4)Evaluation and Decision of each hypothesis; (5)Forming a grand plan; (6)Forming a detailed plan; (7) Making the procedures to sove the problem by PERT (Program Evaluation and Review Technique); (8)Action; (9)Verification; and (10)Conclusion.

Now, we can explain detailed procedure of the KJ method for each step. The original KJ method contains four basic procedures.

1) Label Making: Each label is often gotten by Brainstorming by A. F. Osborn[21]. 2) Label Grouping: It consits of collecting labels, grouping and naming, nestings of groups and naming. This label grouping is most important to get a hypothesis. The essense of the label grouping is, Prof. Kawakita says, to listen carefully to what the labels are trying to say. 3) Chart Making. The maked chart is called A-type of KJ method. 4) Verval or Written Explanation: The explanation is called B-type of KJ method.

From the viewpoint of engineering sense, this figure is fit to implement the creative thinking support system. Namely, human creative thinking processes consists of (1) Divergent thinking process from A to C, (2) Convergent thinking process from C to D, (3) Idea crystallization process at the point D, and (4) Idea verification process from D to H.

As the result, there are two type of abduction researchES in Japan. The first type is Abduction (or Creativity) Support System in the following; (1) Divergent thinking support system like Keyword Associator[22], etc.; (2) Convergent thinking support system like D-Abductor[23], GRAPE, KJ Editor[24], GUNGEN[25], etc. The second type is Abduction System by machine in the following: (1) Hypothetical Reasonig System like HRS, etc.; (2)Knowledge Acquisition Support System like KAISER, etc.

3 Decision Support Groupware GRAPE

We can show you our AI approach to build creative problem solving support system. Using meta-programming in Prolog, we developed several AI systems. This figure shows our total image of HRS and KAISER. The central part acts ass a hypothetical reasoning function. It forms consistent explanations of given observattions. The system employs three kinds of knowledge acquisition functions; knowledge assimilation, knowledge accommodation, and knowledge transaction control. Knowledge assimilation means adding new facts or rules to the KB, without violating its consistency. Knowledge accommodation means consistenly modifying the KB, when adding new correct facts or rules to it. Knowledge transaction control means an adjustment of knowledge assimilation and knowledge accommodation in a given transaction span.

We can implement a hypothetical reasoning system, an inductive inferencew system and an analogical reasoning system, using meta-programmming in Prolog. But, we find another hard problem, that is, Barrier of Complexity.

Let number of hypotheses be one hundred. The number of all possible hypotheses generated and tested by our system

is the 30 power of 10. Assume that we have an ideal super 5G machine. The speed of machine is estimated as 10 GLIPS. LIPS means Logical Inference Per Second. Our machine must run the 12.5 power of 10 years to solve such combinatorial problem. That is the problem.

We were able to build several type of creative problem solving support system. But, we can get another severe problem. It is "How to solve the barrier of complexity ?." To solve this problem, we paid attention to groupware approach. The basic ideas were gotton by Colab[26] and KJ method. Then, we developed new type of groupware GRAPE.

Colab of Xerox's Park is a group decision room with computer support functions for collaboration and problem solving. The basic design concept is WYSIWIS(What You See Is What I See), that is information sharing for everybody. The system has three functions. They are Boadnoter, Cognoter, and Argnoter. The Cognoter of Colab consists of three procedures, that is, Brainstorming, Organizing(Relating), and Evaluating(Clustering). Note that procedures of the KJ method are similar to Colab.

In case of KJ method, the procedures consists of Brainstorming, Clustering(collecting, grouping and naming, nesting of groups and namimg), Relating(mapping and relating), and composition. The difference between Colab and KJ method is an order of Organizing and Evaluating. We changed the order of Evaluating(Clustering) and Organizing(Relating) like KJ mnethod. Then, we designed and implemented our system GRAPE on Prolog machine PSI. GRAPE has 3 modules in the following.

(1)Initialization Module: In this module, we decide the coordinator and the other participants.

(2)Knowledge Acquisition Module: This module has 5 procedures.

(2.1)Candidates acquisition: This procedure supports acquisition of the candidates, using WYSIWIS interface from all the participants(incuding the coordinator).

(2.2)Candidates structuring: This procedure supports acquisition of the similarity value between each candidates, structuring the candidates using Fuzzy Clustering, and acquisition of the names of the clusters in the structure.

(2.3)Attributes acquisition: This procedure supports acquisition of the attributes distinguishing the clusters and the candidates using the elicitation method of PCP(Personal Construct Psychology) by Kelly[27].

(2.4)Attributes structuring: This procedures supports acquisition of the dependency between each attribute and structuring the sttributes using Extended ISM [12].

(2.5)Classes evaluation: This procedure evaluates the importance between the attributes anmd the mutual importance between the candidates with each attributes using AHP.

(3)Calculation Module: This module integrates the evaluation of the candidates from the results of AHP.

Procedure	GRAPE	KJ method
Input	Input of Hypotheses like Brainstorming	Making Cards by Brainstorming
Structuriz ing Hypoth eses	Fuzzy Clustering based on Similarity × (Input of Similar Properties) △	Collecting Cards based on Similarity Naming each Group of Cards(Indexing) Nesting of Groups and Naming
Structuriz ing Proper ties(Crite ria)	× Extended Interpretive Structural Model ing based on Dependency Analysis	Mapping the Nested Structure to the 2 Dimension Space Making Relationships among Groups Clear(Cause-and-Effect Property, Implication Property, etc.)
Determinin g Evaluati on Structu re	Analytic Hierarchy Process (Subjective Bottom-up Judgement by Pairwise Comparisons)	Subjective Top-down Judgement by All Participants
Plan Gener ation	Parallel Constraint Solving	PERT Deployment by KJ Method B'-type

Table 1 GRAPE and KJ method

For the limitation of the space of the paper, the demonstration of GRAPE is omitted. See the paper[5]. The next table 1 describes the comparisons between GRAPE and KJ method. The differences are "Nesting of Groups and Naming", "Mapping the Nested Structure to the 2 Dimension Space", and "Top-down(or Bottom-up) Judgement", etc.

GRAPE system can solve the problem of the following application areas: Group Decision Making, Mutual Agreement Support, Evaluation of Multimedia Software, Decision of the Position, Evaluation of Training/Education Effect, Conflict Analysis, and so on. GRAPE is a cooperative problem solving support environment. But, it is not a cooperative creativity support environment. Because it has a convergent thinking support function, but it has not a divergent thinking support function. It is a group DSS, not a consensus making support system. Our final goal is to build an intellectual facilitation system of creative activities. In the next chapter, we will talk the consensus making support system.

4 QDA based Consensus Making Support System

We are now studying and investigating Group DSS for consensus formation on mutimedia groupware Office Mermaid of NEC. The essential concept of our system is QDA in Fig. 2. Then, first, we'll tell you a QDA methodology[4].

QDA is a methodology how to convert users' requirement quality to developers' quality element. It is necessary to give a relationship matrix between requirement quality and quality element. Note that ,in the beginning, users' requirement quality and developers' quality element are structurized by ISM and AHP. Fig. 3 is an example of relationship matrix for ideal park.

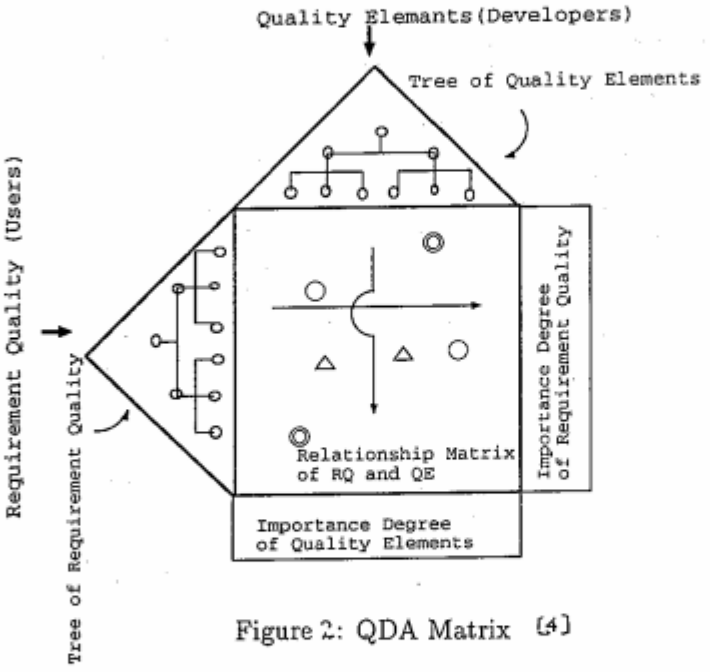


Figure 2: QDA Matrix [4]

Quality Element / Requirement Quality	total area	green area	condition of location	access way	management system	facilities for entertainment
relax	△	◎				○
easy to use			○	◎		
safe			△		◎	△

Figure3: An Example of Relationship Matrix for Ideal Park

Fig. 4 is our system configuration. Our system consists of two modules, that is, Requirement Acquisition Module and Requirement Function Analysis Module. The first module Requirement Acquisition Module consists of three procedures: (1)Extraction of Requirement Quality and Quality Element by Nominal Group Technique like brain writing; (2) Structurization of requirements from users/developers by ISM; (3)Caluculation of Importance Degree by AHP. The second module Requirement Function Analysis Module consists of another three procedures: (1)Decision of Relationship Matrix by Delphi method; (2)Tranformation of Importance Degree by Moore-Penrose Generarized Inverse Matrix[28]; (3)Consensus Formation Support Interface by Graphic Representation, eg. constellation graph.

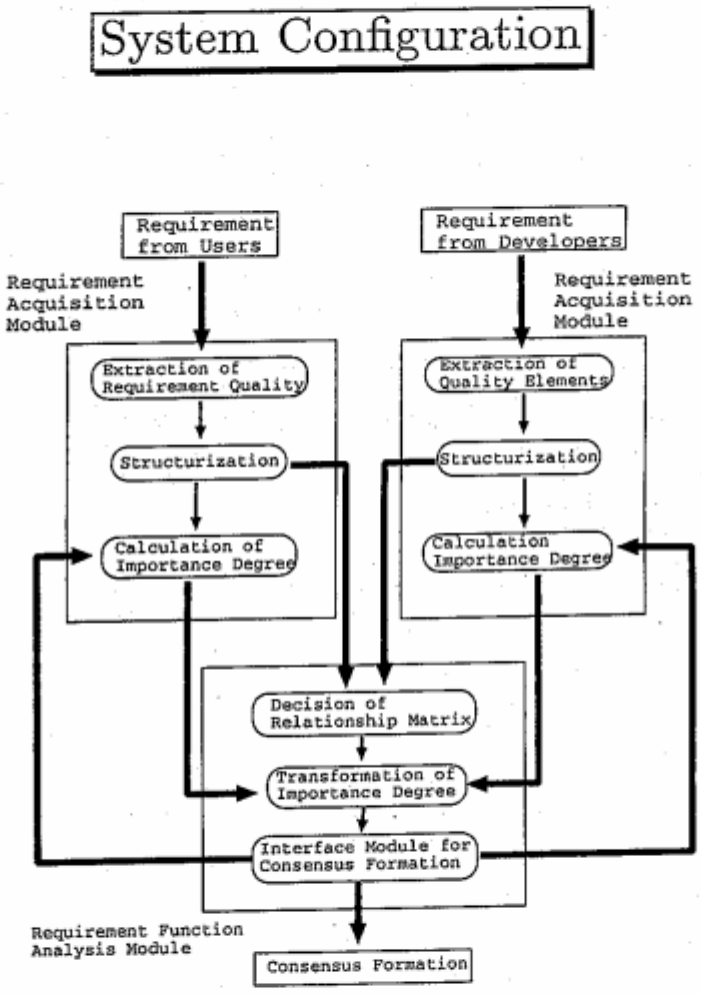


Figure 4: System Configuration

Using relationship matrix, we can tranform each importance degree of requirement quality to its corresponding importance degree of quality element, mutually.

$$v' = Wu \quad (1)$$

$$u' = W^{-1}v \quad (2)$$

where u is an importance degree vector of users' requirement quality, v is an importance degree vector of developers' quality element, W ia a relationship matrix, v' is an importance degree vector of quality element calculated from

the viewpoint of users, and u' is an importance degree vector of requirement quality calculated from the viewpoint of developers.

Generally speaking, the matrix W is a rectangler matrix, not a square matrix. Then it is difficult to computate its inverse matrix. Then, our goal is "How to minimize $(u-u')^2+(v-v')^2$, interactively ? "

We are now implementing another QDA-based function design support system[29] reflecting users' requirements. It is now developing on the personal computer PC98 of NEC. They are composed from four function module, that is a requirement acquisition module, a requirement function analysis module, a graphical interface module for consensus formation, and a rational selection module of alternatives. The differences between this new system and the above-mentioned system will be described at the workshop.

5 QDA based DSS with Subjective and Objective Judgement

In view of present situations surrounding decision making, the method of decision support must cope with fuzziness, uncertainty, large scale and complex problems. It also has to reduce the decision maker's mental load. It goes without saying that the method of support must find reasonable and nearer the optimal solution for the decision maker.

Decision making is always affected by personal view, sense and feeling. That is, people make decision based on their view of worth. Decision making is essentially human, and finally entrusted to the personal subjective evaluation. However, this may be wrong decision depending on only subjectivity. When the problems get complicated and many criteria exist, it is very difficult that people make decision based on their view of worth.

On the other side, the evaluations based on mathematical approach have solution with definite numeral reason. But, this is difficult to apply to the ill-structured problem with difficulty of structuring mathematical model. This can be explained by limit of dealing with criteria that cannot be expressed by quantity such as liking or feeling.

Our proposed method gives careful consideration to these condition to make better decision. The method takes care of the following: (1)To get all the necessary knowledges about all possible alternatives; (2)To have reason in selection and to form worth system as criteria of selection; (3)To evaluate with flexibility.

The method uses AHP and DEA(Data Envelopment Analysis)[30] to make subjective judgement with rationality. AHP mainly composes the evaluation of the method. Because decision making is strongly affected by subjective judgement with personal criteria in the end. DEA is used to realize features of alternatives analyzed objectivity with data.

AHP is a method based on pairwise comparisons to express subjective worth. In the proposed method, the main new trials are as follows: (a)To classify criteria into subjective ones and objective ones; (b)To refer data in decision of weight between alternatives about objective criteria.

In this method, subjective criteria are placed as criteria forming the subjective value of evaluation with personal view of worth and objective criteria are placed as criteria forming objective the value of evaluation with value of data.

This classification is useful in making subjective evaluation and evaluation referring data. So, alternatives are evaluated reasonable without depending on subjectivity, and the decision maker can lighten his mental load.

The decision of weights between subjective and objective criteria is made as follows.

In first, the decision maker compare between subjective criteria, calculate their weights. Next, they compare the relations between subjective criteria and objective ones, give relevance degree. So, the weights of subjective criteria are changed into the weight of objective ones. This refers the method of QDA. It is the method to deploy from required quality to quality elements. As the weights of AHP mean ratio scale, the weights of this method don't mean exactly same. However, it is doubtful that the weights of AHP become strictly ratio scale. If it is reasonable that the weights is thought in order(or space), the weights of this method are satisfied to a certain extent. Before anything else, objective criteria got weights and values of pairwise comparisons, so it becomes stimulation to think pairwise comparisons between objective criteria. If the decision maker don't satisfy with this weights or values of pairwise comparisons, he ought to make sensitivity analysis.

Thus, the decision maker can get the weights of between subjective criteria and between objective ones. The subjective criteria with strong dependence on objective ones are excepted criteria. Because they may cause reverse order and greatly influence on result. The extreme low weights also excepted criteria. Thus, the criteria that decide actual weights, are selected.

The weights of alternatives about objective criteria refer data. Therefore, the decision maker have only to compare alternatives of the most desirable value of data to ones of the most undesirable value of data. The value gives reasonable values of all pairwise comparisons.

We tested it, using this system. We examined how to make evaluation process alternatives and final evaluation of alternatives. The problem that this method is applied, considering the character of it, must have various kinds of data and complicated criteria.

In the method that the decision maker decide weights of criteria, the criteria are extracted from the words of himself, so it is easy to image and think. Moreover, by thinking connection between subjective criteria and objective criteria, the decision maker can analysis complicated trade-off relations between criteria, and promote recognition for the problem. On the other side, if the decision maker understand fully the problem, this method does not have so meaning by classifying criteria into subjective and objective ones. Moreover, if there is strong dependence each other between subjective and

objective criteria, pairwise comparisons between subjective criteria does not almost have meaning and classification of criteria does not have much effect. In result of comparison total weights by this method with total weight by normal method, the both are same order and don't have so difference of values. In pairwise comparisons between alternatives about objective criteria, the method that this paper proposed is effect to prevent from misunderstanding with lack of information and enforce the decision maker to judge with rationality. We could also confirm to reduce the decision maker's mental load, because the decision maker have only to make a pairwise comparison. He must pay attention to the point that a wrong value of pairwise comparison leads all wrong values of pairwise comparisons.

Although we thought to utilize analysis results based on DEA for narrowing of alternatives, we could not get very good effects because the weights weren't limited. So, the weights need limit by utilizing order relation of weights with AHP. This test showed that the more the problem becomes large scale and complicated, the more the method becomes effective.

6 Conclusion

This paper shows two type of group decision support systems. One is a decision support groupware GRAPE. Another is QDA-based DSS reflecting requirements from users and developers. Our system supports a group decision / consensus formation between users and developers by using system modelling method, KJ method, and QDA method. Each system is a bottom-up type group decision system with convergent thinking support functions.

The final target of our research is combining a divergent thinking support system[22,31] with a convergent thinking support system[5,7,9], and making a creative group decision support system. Such system becomes a prototype of human thinking support groupware for creative problem solving.

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