The Research on Giant Complex System using Intelligent Decision Support System

Li Jie[1], Wang Aimin[2]
[1, 2] School of Computer and Information Engineering
Anyang Normal University
Anyang, China
[1] Shenyang Institute of Computing Technology
Chinese Academy of Sciences
Shenyang, China
ljjacky@vip.sina.com, wam508@126.com

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ABSTRACT: *Mankind is confronted with an increasingly complex system, especially the major decision issues, such as organization and management, coordination, planning, forecasting, controlling and so on. Due to the complexity of the system, many fuzzy factors and the limitations of the existing complex giant system theory, there are still many problems to be solved. The research on the giant complex system based on the theory of fuzzy decision theory theoretically had been proving the reliability of the group decision and has established "the multi-judgments information" fuzzy synthesis computational method. It has designed the corresponding multipurpose intelligent decision support system IDSS.*

Categories and Subject Descriptors:
I.2.11 [Distributed Artificial Intelligence]; Intelligent Agents
H.4.2 [Types of Systems]; Decision Support

General Terms: Decision Support Systems, Intelligent Decision Making, Fuzzy Systems

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1. Introduction

With the continuous progress in modern science and technology and the rapid economic development, the resource environment and the ecological environment are becoming worse and worse. Mankind is confronted with an increasingly complex system, especially the major decision issues, such as organization and management, coordination, planning, forecasting, controlling and so on [1]. The characteristics of these questions display in the more and more complex level structure , in the more and more big space scale, in the more and more quick time criterion, in the more and more widespread consequence and more and more profound influence [2]. Due to the complexity of the system, many fuzzy factors and the limitations of the existing complex giant system theory, there are still many problems to be solved [3].

This paper studies the theory and method based on the combination of theory and practice of fuzzy math principles which is supposed to be used in the giant complex system. It has designed the major decision making intelligent decision support IDSS support system which can support the four group decision systems: "*Comprehensive evaluation of the level of development of the whole city*", "*Comprehensive evaluation of the state-owned large and medium-sized enterprises*", "Comprehensive evaluation of higher education" "*University research funding system longitudinal evaluation of the overall effectiveness*".

2. Giant Complex Decision-making System

This paper discusses the basic method of the enormous complexity of the decision-making system. First, a huge complex system is decomposed into a series of mutually dependent and interrelated subsystems (such systems at the various levels, the various stages); and through the establishment of hierarchy in the system, the links between the stages, we can change the giant decision-making system for solving complex problems into a series of simple subsystem for decision-making [4]. The decision-making process can be roughly divided into four steps: setting a target, proposing the plan, selecting decision-making plan, carrying out the plan. Its relation like figure 1 shows:

The so-called complex great system is refers to such system [5]: (1) system itself can exchange material, energy and information with the periphery environment. (2) System contains a number of subsystems. (3) the types of subsystem are in a big number. (4) system and some middle-level factors are not clearly defined attributes (Fuzzy).

Decision practice has proven that in order to achieve the enormous complexity of a scientific decision-making system [6], we can make full use of the existing giant complex system theory, and use the knowledge and experience of the person who can not be called the "*science*" person. The system is due to some special factors, there is no absolute clear boundary, with the intermediary transition. It needs to establish the corresponding decision-making theory and the method regarding this kind of system policy-making question.

However, the fourth characteristic of the giant complex system makes the divisible condition unsatisfied in the ordinary circumstances. How does this kind of question achieve the ideal decision-making? At present it is realized through the group decisions. Because the fuzzy from the mutually restricting and interacting factors, it needs to make a farther study about a huge complex system of the fuzzy decision theory and methods. This paper will discuss the following three questions: (1) to theoretically prove the reliability of group decision-making. (2) to study the synthesis of the theory and method of decision-making information. (3) to develop the Intelligent Decision Support System of handling large-scale fuzzy (decision).

3. The Reliability of The Group Decision-making

This section discusses the group decision request: groups only have common interests and objectives, and there is no obvious conflict besides the different understanding between the individuals. As individuals have the same interests and have the different understandings, then this kind of decision-making is not all individual participants, and those should be a higher level of the individual, namely experts. Such issues, in general, there is objectively right or the best program. If we do not consider individual differences in the level of awareness, but simply focus the individual, it would not be possible to ensure that the chosen option is the best, or the right one. Evaluation of the existing groups has noted the individual level of understanding difference in expert's choice. But to the analysis of the results from the experts, it is common to make the evaluation concentration (qualitative assessment based on the number of votes; Quantitative evaluation of admission average), but has not carried on the inspection to various experts plan choice, therefore lacks the profound theory proof and the confidence.

Here we take the collective evaluation about some factor μ as the example to carry on the theoretical discussion from the probability angle to it.

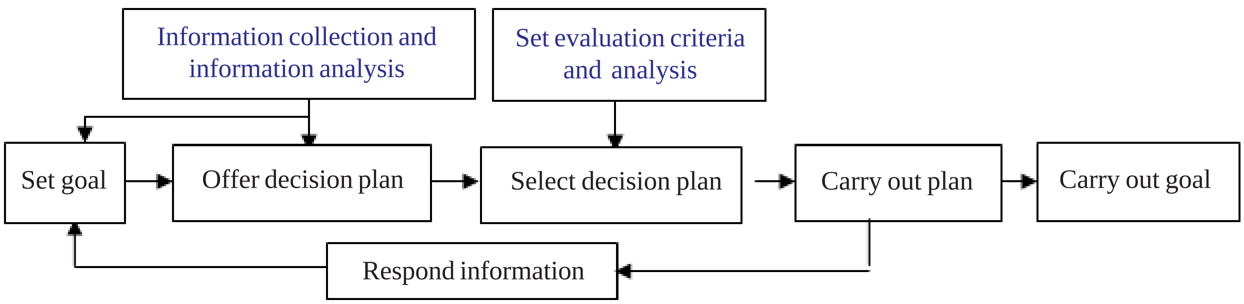


Figure 1. A programme on decision process

Supposes μ is an assigned evaluation factor, and its corresponding evaluation value is σ. Meanwhile μ has the objective value. Then the group evaluation to μ is:

$$F = (\sigma, I, X) \tag{1}$$

Because in the usual situation, the factor ì has not been clear about the extension of the soft target, thus expert's evaluation is not always correct, this is a random event. The probability which the experts have commented depends on the evaluation ability of the expert and the difficulty of the problems. An expert on the evaluation capacity in certain period of time can be considered stable. Therefore, if there is a series of theoretical difficulty of a certain category of the similar evaluation, then the specialists should have the right frequency stability limit, the limit is the probability of the correct evaluation of experts.

Definition: supposes the objective value of σ is σ^*, and the evaluation value is Xi from the expert i. $If = |Xi - \sigma^*| \leq \alpha$, then we can call the evaluation value Xi from the expert i is accurate, briefly Xi is α.

Supposes the probability of α for Xi is Pi, makes $P = (P_1, P_2, \ldots, P_n)$, then the group evaluation about μ can be expressed:

$$H = (\sigma, I, X, P, \alpha)$$

Then σ, I, X are consistent with (1), and α is the precision.

Theorem 1: Supposes $H = (\sigma, I, X, P, \alpha)$, arranges X_1, $X_2, \ldots, X_n$ from the small to the big number, as well supposes $X_1 \le X_2 \le X_3, \ldots \le X_n$, the middle number is X_T

$$X_T = \begin{cases} X_{(n+1)/2} & (n \text{ is odd number}) \\ X_{n/2} & (n \text{ is even number}) \end{cases}$$

Supposes μ_n is the established numbers of α in X, when $\mu_n > n/2$, then $|X_i - | \le \alpha$, and σ^* is the objective value of α. This theorem establishment is obvious, and the proof is ignored.

Theorem 2: Supposes $H = (\sigma, I, X, P, \alpha)$, μ_n is the appearing times for X_i when the precision is α. A_k shows that A_k is accurate in the k^{th} evaluation. If $A_1, A_2, A_3, \ldots, A_n$ are mutually independent, we can use P_K to show the evaluation probability of α in the k^{th} time, and when $\forall K \in I = \{1, 2, \ldots, n\}$, $P_K \ge r > 1/2$, then $\exists N > 0$, when $n > N$, the middle number X_T is accurate to α, then probability is 1. That is when $n > N$, then $P\{|X_T - \sigma^*| \le \alpha\} = 1$

Prove: according to the suppose and Kolmogorov theorem, then

When $\forall \varepsilon > 0, \exists N > 0$, and $n > N$

Because

$$\subseteq \{u_n : u_n > n/2\}$$

(Takes $\varepsilon < r - 1/2$)

$$\subseteq \{u_n : u_n \ge (r - \varepsilon)\}$$

Then when $n > N, P\{\mu_n > n/2\} = 1$, from theorem 1, when $n > N, P\{|X_T - \sigma^*| \le \alpha\} = 1$.

The theorem says if the expert evaluation of the probability value is more than half, and

$$\{u_n : \left| \frac{u_n}{n} - \frac{1}{n} \sum_{k=1}^{n} p_k \right| \le \varepsilon\} \subseteq \{u_n : u_n \ge \sum_{k=1}^{n} p_k = n\varepsilon\}$$

evaluation is independent of each other, then, when the expert population is enough, the evaluation vector of the probability is the middle number 1. The theorem is proved theoretically that under certain conditions, group decision making results are reliable.

4. Multi-judgement Information Fuzzy Synthesis

For the same level, the same stage of the decision-making group, its information can be synthesized using fuzzy treatment. Here it studies the different expert group in the different place has made the many criteria synthesis problems which makes to the identical decision-making object.

s	g_1	g_2	$\cdots$	g_m
y_1	$f_1(y_1)$	$f_2(y_1)$	$\cdots$	$f_m(y_1)$
y_2	$f_1(y_2)$	$f_2(y_2)$	$\cdots$	$f_m(y_2)$
$\cdots$	$\cdots$	$\cdots$		$\cdots$
y_n	$f_1(y_n)$	$f_1(y_n)$	$\cdots$	$f_m(y_n)$

Table 1. $f_i(y_i)$ is the evaluation from the criterion g_i to the plan y_i

Supposes $Y = \{y_1, y_2, \ldots y_n\}$ is the plan set, $G = \{g_1, g_2, \ldots g_m\}$ is the multi- criteria set to the plan, records $f_i(y_i)$ is the evaluation from the criterion g_i to the plan y_i, then the original data Table1 is obtained.

To each criterion g_i, we should establish the superior fuzzy relations from y_k to y_i.

$$u_j^*(y_k, y_l) = \begin{cases} 1, \ldots\ldots\ldots, f_j(y_l) - f_j(y_k) \le 0 \\ 0, \ldots\ldots\ldots, f_j(y_l) - f_j(y_k) \ge s_j \\ \left[1 - \frac{f_j(y_l) - f_j(y_k)_j}{s_j - u_j}\right]^{\lambda}, 0 < f_j(y_l) - f_j(y_k) < s_j \end{cases} \quad (2)$$

Among them, $\lambda > 0, s_j > 0$ are Parameters to be determined, it may extract the fuzzy superior relational matrix by (2) type.

$$Rj = (\mu_j^*)_{n \times n} \qquad (j \le m)$$

Regarding criterion g_j, if $f_j(y_2) - f_j(y_k) \ge s_j$, then $\mu_j(y_1 - y_k) = 0$, which is no longer superior than y_1. But if it has $g_j (i \ne j)$, y_k is superior than y_1, overall y_k is possibly superior than y_1. If $f_j(y_1)$ is bigger than $f_j(y_k)$, although other factor y_k is the superior criterion, y_k may still be excluded from the program. Obviously, it needs to introduce the inconsistency of fuzzy. To criterion g_j, the inconsistency relation from y_k to y_1 is:

$$v_j(y_k, y_l) = \begin{cases} 1, \ldots\ldots\ldots, f_j(y_l) - f_j(y_k) \le u_j \\ 0, \ldots\ldots\ldots, f_j(y_l) - f_j(y_k) \ge s_j \\ \left[1 - \frac{f_j(y_l) - f_j(y_k)_j}{s_j - u_j}\right]^{\lambda}, 0 < f_j(y_l) - f_j(y_k) < s_j \end{cases} \quad (3)$$

Among them, $\lambda > 0$, $\mu_j > 0$ are Parameters to be determined, then we can extract fuzzy inconsistent

$$V_j = (V_j)_{n \times n} \ldots\ldots\ldots, j \le m$$

matrix from (3):

To weight coefficient

$$W_j \succ 0, \sum_{k=1}^{n} W_j = 1$$

To establish the overall fuzzy consistent relations

$$C_J(y_k, y_l) = \sum_{j=1}^{m} W_{juj}(y_k, y_l) \quad (4)$$

$$u(y_k, y_l) = \begin{cases} C_j(y_k, y_l), \ldots\ldots\ldots\ldots, C_j(y_k, y_l) \geq V_j(y_k, y_l) \\ \dfrac{C_j(y_k, y_l)}{1 - C_j(y_k, y_l)} \prod_{j \in A} (1 - V_j(y_k, y_l)), \ldots, C_j(y_k, y_l) < V_j(y_k, y_l) \end{cases} \quad (5)$$

The overall fuzzy superior relations are

Among them $A = \{ j: C(y_k, y_l) < V_j(y_k, y_l)\}$, we can extract the overall fuzzy superior relations matrix:

Obtains the fuzzy superiority relations by the R type

$$R = (u)_{n \times n}$$

$$d(y_k, y_l) = \begin{cases} u(y_k, y_l) - u(y_l, y_k), . \, u(y_k, y_l) \geq u(y_l, y_k) \\ 0, \ldots\ldots\ldots\ldots, u(y_k, y_l) \geq u(y_l, y_k) \end{cases} \quad (6)$$

Obtains the fuzzy superiority relations by the (6) type

$$D = (d)_{n \times n} \quad (7)$$

from $d'(y_k, y_l) = 1 - d(y_k, y_l)$

Obtains fuzzy decision matrix

$$D' = (d')_{n \times n} \quad (8)$$

makes:

$$d'(y_k) = \min_{y_l \in y} d'(y_k, y_l)$$

and to y_{k0}, it satisfies

$$d'(y_{k0}) = \max_{y_k \in y} d'(y_k) \quad (9)$$

Then the plan y_{k0} is the most satisfactory decision.

For example, supposes $Y = \{y_1, y_2, y_3, y_4\}$, $G = \{g_1, g_2, g_3\}$, Criteria for evaluation data is

	g_1	g_2	g_3
y_1	5.2	5.6	2.6
y_2	7.1	4.5	1.8
y_3	3.8	8.0	6.5
y_4	6.4	4.2	9.0

Takes $\lambda = 1$, time, $s_j = 2, u_j = 5 \quad (j = 1, 2, 3)$

$$(W_1, W_2, W_3) = (0.25, 0.4, 0.35)$$

Separately by (2), (3), (5) the formula may obtain

$$R = \begin{bmatrix} 1 & 0.7 & 0.12 & 0 \\ 0.64 & 1 & 0.2 & 0 \\ 0.83 & 0.75 & 1 & 0.4 \\ 0.72 & 0.85 & 0.6 & 1 \end{bmatrix}$$

May obtain by (6) the formula

May obtain by (7) the formula

$$D = \begin{bmatrix} 0 & 0.12 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.7 & 0.73 & 0 & 0 \\ 0.72 & 0.85 & 0.2 & 0 \end{bmatrix}$$

$$D' = \begin{bmatrix} 1 & 0.88 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0.3 & 0.27 & 1 & 1 \\ 0.28 & 0.15 & 0.8 & 1 \end{bmatrix}$$

May obtain $\{d'(y_1), d'(y_2), d'(y_3), d'(y_4)\} = \{0.28, 0.15, 0.8, 1\}$ by (8).

The plan y_4 is the most satisfactory decision by (9).

5. Intelligent Decision Support System Development

Intelligent Decision Support System IDSS is developed on the basis of the relevant decision software which is made by the author through the more than three years of research and efforts. And it is funded by the Higher Education Management Institute in China. The system has been in use more than 30 units and departments, and good results have been achieved.

5.1 The Basic Function of IDSS

IDSS may achieve the following three goals: (1) to be the tool which can help the decision management department finish the choice and the optimization about the actual decision-making model. (2) to help the researcher test new ideas and the new algorithm simulation system. (3) to realize automatic synthesis of information, coordination and decision-making and information output function. The system specifically supports the following five large-scale decision-making activities.

(1) City's overall development of the Comprehensive Evaluation IDSS-1: the system has 48 secondary subsystems, the 6-8 three-tier subsystems, and part of the three-tier subsystem also has set 2-6 4-level of subsystem. Each final subsystem has separately contained 8–36 inspections targets. The correlation qualitative evaluation factor design is 3 – 6 evaluations ranks. The literature [6] the center information processing model has partially applied to this subsystem.

(2) Comprehensive evaluation of higher education IDSS-2: is based on the international indicators to evaluate the effectiveness of higher education, "*Education Development Program*" and the specific requirements from the current

development status of higher education. It may choose and coordinate the corresponding subsystem according to the different situations. IDSS-2 application can obtain the comprehensive efficiency evaluation (qualitative and quantitative) on the art and science department. Among them, art can support 28 subunits, such as departments, research institutions, centers and so on; science can support 56 subunits, such as departments, research institutions, centers and so on. And each two-level unit may most support 19 three-level units. To every factor, the qualitative comment is set the grades from 4-6. The information synthesis algorithms, evaluation factors set and their corresponding weights distribution can be seen in the literature [7].

(3) Comprehensive evaluation of the state-owned large and medium-sized enterprises IDSS-3: is developed on the basis of the literature [6]. It has eight sub-systems; each secondary subsystems are designed with a corresponding performance metrics. Related information processing method is similar to literature [7].

(4) University research funding system longitudinal evaluation of the overall effectiveness IDSS-4: has been separately used to evaluate the three subsystems that is the school to issue the funds, the education committee to issue the funds and the science committee to issue the funds. Each subsystem has two evaluation models for "*social science funds*" (the assessment unit can choose the corresponding model according to the original source of the funds). "*Natural Science Funds*" can offer six categories of models to choose from a total of 48 evaluations for users. "*Social Science Funds*" can offer five types of models to choose from a total of 58 evaluations for users.

The above 4 subsystems application method, decision-making model establishment, inspection target and evaluation rank connotation, and value transformation formula can be learned from the intelligent help of IDSS or from the introductions of IDSS.

5.2 The Overall Structure of IDSS

The system uses modular architecture. It is composed by the control module, metaknowledge base, the level goals the knowledge base, the inference machine, the target inference engine, the knowledge base management module, the knowledge acquisition module, the input module, and the output module, intelligent help module, the user's information management module, model simulation module. System architecture is shown in figure 2.

The control module carries on the thick line control to the system, manifests the general character of the control, it does not change along with the knowledge library change. The metadata knowledge base is composed by a description of metadata rules, which reflects the experts with specialized knowledge, that is, to analyze specific issues, for the control of knowledge. Inference Engine will decide the strategy and direction of solving the problem by using the metadata knowledge base according to the current problems and its characteristics.

Target level inference engine is designed for problem solving, which is used the reasonable inference mechanism. This kind of inference is quite direct-viewing, can simultaneously seek all possible solutions, and is easy to insert each kind of indefinite inference. It is very close to the thinking method of the human expert to handle the reasoning problems.

The knowledge in the target level goal base is mainly about the decision objectives, including Fuzzy opinion decision-making (qualitative), Fuzzy intention decision-making (qualitative and quantitative), Fuzzy preference ranking (quantitative), Fuzzy decision regulatory category (qualitative, quantitative) model and the corresponding information synthesis algorithm.

The knowledge management module function is to help organize the current problem related knowledge in the decision-making process. The module also provides the user with a functional tool of self-adjusting, expansion and re-definition. To prevent accidental damage system, the function of the module only allows designated users to carry out.

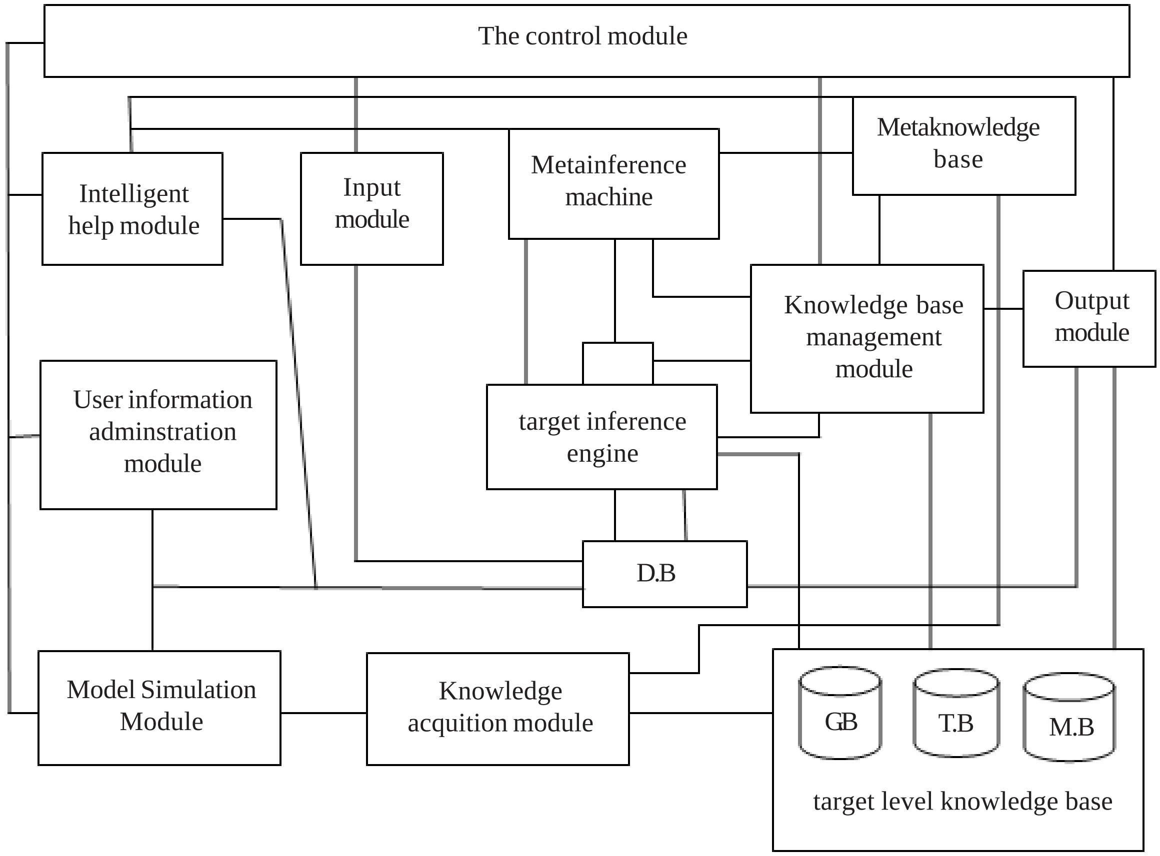
Knowledge acquisition module is to support the users to build up the knowledge base.

Input Module is to select the same diagnosis information to give the system by moving the cursor. And we can use the keyboard to give the diagnosis (decision) to the system in groups.

Output module split screen certain windows. The system can display the current IDSS structure diagram, the related prompt information and decision-making result in decision-making process. Users can connect printers, and print out the information.

Intelligent help module: can offer users on how to use the knowledge in IDSS and expertise in the field of decision-making and management system, operating rules, professional terminology, etc. IDSS users may at any time request the help system in the operation of any interactive interface on the current phase. Intelligent module will help make the corresponding text shown in the information service window. When users make mistakes in the operation, the system will give suggestions. The subsystem can also serve as a new teaching system which can operate independently User information administration module.

User information administration module: can manage all kinds of information which is related to the decision system, such as the decision system primitive power vector, the various factors corresponding evaluation, the consistency information, the precision α, the coordinated condition, the comprehensive decision-making production



Note: D.B—data Base M.B—model Base T.B—Select Test Knowledge Base
G. B—graph Base

Figure 2. Total structure of the IDSS

condition and so on. The module is a user-oriented information inquiry system.

Model Simulation Module: The basic function is to carry on the simulation according to the model and the environmental condition. The module has two roles : 1) to provide an ideal system for the analysis of simulated operational data; 2) to examine the rationality of the real model selection, and forecast the possible running condition in the decision-making process.

IDSS has the following characteristics:

• It has good people — machine interface. It uses the motion cursor and keyboard to input, the operation is extremely simple. It selects the split screen method to simultaneously demonstrate the current decision-making process diagram of IDSS and the decision-making space. Thus it can give more information and enhance the transparency of the decision.

• With strong graphic interpretation functions, thus it greatly improves the people's psychological acceptance of the decision-making process.

• It selects the many kinds of knowledge expression method and many kinds of information synthesis algorithm to express their knowledge in various fields needed for the decision.

• The system knowledge uses "*the level*", and "*a dividing style*" structure, and according to the different decision-making model structure and the function piecemeal, to improve the decision efficiency.

• The system program uses the modular design method. It is easy to adjust the expand.

• The system model can accommodate all kinds of imprecise reasoning modules.

• The inference process conforms to the person's direct-viewing.

5.3 The Primary Function of System Design

5.3.1 Online help

Because MUDSS is more than technical integrated systems, and involves the various knowledge, thus the on-line help to the user is extremely essential. MUDSS online help function will go through the whole process. All these functions are realized through the system state tracker, working methods controller, dynamic indexing table and the online dictionary. Systematic state tracker can automatically record the location of the systematic current interactive interface in the entire system control route tree. At any human-computer interaction stage in the system's operation, the system has two options for work: the way of implementation and the way of helping. In the implementation mode, each option of the interface corresponds one procedure. In the explaining mode, the system can make confirmation about the current interface according to the recording from the tracker and dynamically produce an option information index table from the corresponding interface. It also can form the online dictionary which needs to take the knowledge from the knowledge storehouse. Moreover, these options are to be regarded as the search keywords for the online dictionary.

When the user needs a system to offer help on the current stage of interaction, he only needs to use a computer mouse to choose the explaining mode and establish an understanding of the choice item. The online help system will automatically choose the selected interpretations and suggestions and display them on the information window which is set by the system.

5.3.2 Interactive Model Selection

It is a very difficult task to achieve scientific decision-making and to correctly choose the model and its information synthesis algorithm, which usually relies on the expertise and experience of the decision-makers. In MUDSS, it has designed to provide the users with a model tool to optimize the module which can offer assistance to help users determine appropriate decision-making model and its information synthesis algorithm through the man-computer interactive method.

MUDSS alternative models: (1) One, two, three levels fuzzy decision (qualitative and quantitative) model; (2) fuzzy views decision-making model (qualitative); (3) fuzzy intention decision (qualitative and quantitative) model;(4) fuzzy ranking priority relationship (quantitative) model; (5) vague category of regulatory decisions (qualitative and quantitative) model.

Above models, synthesis algorithm can choose one of the following formulas according to the specific information.

(1) $''\wedge'', ''\vee'' : a_i \vee b_j = \max(a_i, b_j),\ a_i \wedge b_j = \min(a_i, b_j)$

(2) $M(\cdot, \vee): b_j = \bigvee_{k=1}^{n} (a_k, T_{kj})$

(3) $''.'' + a . b = ab,\ a + b = a + b - ab$

(4) $''\Box'', ''\Box'': a \Box b = \max(0, a + b - 1),\ a \Box b = \min(1, a + b)$

(5) $''\beta'', ''\delta'': \alpha\beta\gamma = \frac{ab}{1 + (1 - a)(1 - b)},\ a\delta b = \frac{a + b}{1 + ab}$

(6) $M(\cdot, +)$: is the general matrix multiplication.

The user can propose the exploratory choice to the model and the algorithm on the actual grasped knowledge and the experience. Decision support subsystem uses the similar type of problems with the example of the model to carry on the simulation decision to the experimental model, and to demonstrate the corresponding decision information in graph contrast analysis window for users to make a choice judgment. If users are not satisfied with the results of the test, they can retest until get the better decision model and algorithm. Users can also make appropriate changes to the model and algorithm according to their needs until obtain the satisfactory choice.

5.3.3 Knowledge-based precision option

In IDSS, we use a knowledge-based reasoning, to calculate precision a, according to the actual data and the decision-making matrix (qualitative or quantitative), for the coordination and decision-making. The process of the coordination is realized through the guide from the service menu.

6. Conclusion

The fuzzy decision theory and method provide an effective tool in the major decisions in production and management. The main program of IDSS is made in the Windows environment by using Microsoft VC++7.0.

IDSS can support decision making in the network environment. (Requirements in operating system on the environment are as follows: require the use of Windows or Windows NT Server 4.0 Ser 2000Server, platform using TCP network protocol agreement. Client operating Windows98/ME/XP/2000 may require each client to install Internet Explorer version 6.0 and above, TCP distribution agreement). From a computer terminal (which can have the appropriate privileges) as decision coordination, policy and decision makers in their respective terminals can complete their decision-makings, and make continuous consultations and coordination until they have met the requirement of accuracy in decision-making.

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