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EXPERT SYSTEMS BASED DECISION SUPPORT SYSTEMS

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Abstract: Decision support system (DSS) represents one of the most important and most rapidly developing research fields in information and decision science. This papert is aimed at designing an expert systems (ESs) based DSS (ESSBDSS) to enhance decision makers' ability in more complex cases. The basic structure and functions of the ESSBDSS are presented. From the aspects of problem decomposing, dynamic combination of multiple ESs, link of multiple bases and decision coordinating, the applications of this ESSBDSS in large-scale decision making processes are described. Finally, a summary and some ideas for the future are also presented.

Keywords: Decision support system, Expert system, Integrating expert systems, Problem solving, Knowledge representation, Reasoning.

1. Introduction

Decision makers often deal with ill-structured problems which, because of their nature, preclude the use of standardized procedures (Duchessi and Belardo (1987)). The term decision support system (DSS) has been used to refer to computer-based efforts aimed at assisting or enhancing a decision maker's decision making ability in semistructured decision tasks (Bonczek et al. (1980), and Keen et al. (1978)). Generally, a DSS consists of a database (DB), a model base (MB), and a user interface (UI) (Sprague (1980)). Three elements are crucial during a DSS-based decision making task: data, analytical and/or computational models, and experience. The conventional DSS design focuses on the support of data, models and their integration. The conventional DSS has been implemented primarily within a single, specific problem domain (Sen and Biswas (1985)) and suffers from drawbacks such as domain-dependence and lack of user-friendliness (Chen (1988)). Sen and Biswas (1985) proposed an expert DSS (XDSS) framework to extend the capabilities of traditional DSS systems and make them more intelligent and user-friendly. In many situations, a DSS with an expert system (ES) will provide direct aid to a decision maker (for example, Biswas et al. (1988)), but in more complex cases, several ESs covering different but related knowledge will be needed (Fraser et al. (1989)). For example, a production manager may have separate ESs advising him on output, materials, planning, selling, and financing. And making a reasonable economic development strategic decision needs the cooperation of experts in population, economics, education, science and technology, systems engineering, management engineering, etc. We propose the multiple ESs based DSS (ESSBDSS) to enhance decision makers' ability in more complex cases (especially to make some large-scale decisions and improve the effectiveness of decision making.

2. The Basic Structure of ESSBDSS

This ESSBDSS consists of a central controller (CC), a UI, meta-level knowledge source (MLKS), blackboard structure (BS), multiple ESs system (MESS), data unit (DU), model unit (MU), and algorithm unit (AU) (See Fig. 1). In Fig. 1, DBMS, MBMS, ABMS and KBMS respectively indicate DB, MB, algorithm base (AB) and knowledge base (KB) management system, DDDU indicates the drawing unit of data for decison making, REG indicates the reasoning engine group, KAM indicates the knowledge acquisition module.

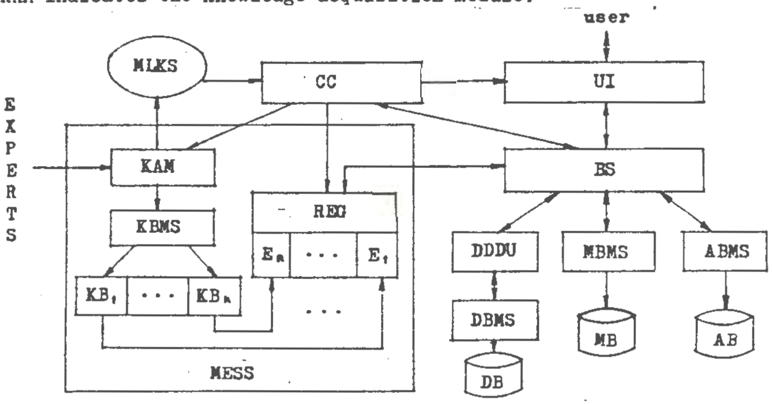

Fig. 1 The Basic Structure of ESSBDSS

Each part of the ESSBDSS has its own functions:

(1) CC: It assists objective analysis, takes charge of transportation of data, knowledge acquisition, REG,UI, and BS, manages every part of this system, and processes what the user asks.

(2) UI: It allows the user to communicate with this system. It has the f-

unctions of menu choosing, question inquiring, graph displaying, result printing and outputting, etc.

(3) MLKS: Meta-level knowledge is the knowledge used to manage knowledge (Davis (1980)). In this system, MLKS controls CC and reasoning.

(4) BS: BS is a scheme for communication among ESs and other knowledge sources, possibly including humans (Hayes-Roth (1985)). In this system, BS permits different ESs to share data and conclusions, each ES and each knowledge source can write their subdecisions and current state on the blackboard; as well, it can read the current states of other ESs and knowledge sources.

(5) MESS: It includes KAM, multiple KBs ($KB_1, KB_2, \ldots, KB_n$), multiple reasoning engines ($E_1, E_2, \ldots, E_n$) and KBMS. Under the control of CC, KAM can acquire knowledge and expertise from multiple experts in different domains, save meta-level knowledge into MLKS and save each expert's knowledge and expertise into each KB through KBMS; multiple reasoning engines can accomplish cooperation of several reasoning engines or independent work of each reasoning engine. So MESS can accomplish cooperation of multiple ESs and independent work of each ES, so as to specify and resolve some large-scale decision problems step by step.

(6) DU: It consists of a DB, DBMS, DDDU and a DB dictionary. It is in charge of collecting, storing, processing, organizing and managing of data.

(7) MU: It includes a MB, MBMS and a MB dictionary. It is responsible for building, revising, adding and deleting of models used in decision making.

(8) AU: It consists of a AB, ABMS and a AB dictionary, and stores many kinds of standard programs, for example, multivariable linear regression programs, forecasting programs, linear programming programs, drawing programs and so on. These are different kinds of methods for calculation and drawing graphs. The ABMS can dispatch and safeguard for the standard programs in AB.

3. The Basic Functions of ESSBDSS

This ESSBDSS has the following functions:

3.1. Multiple knowledge representation

There are several schemes to represent domain knowledge and expertise (Nau (1983)). The most prominent are production rule formalisms, frame-based structures, network structures (Rich (1983)), procedures and logic.

We used produotion rule formalisms in the DSS for produotion planning (Wang (1991)). ESSBDSS oan provide several knowledge representation sohemes to represent domain knowledge and expertise of experts and skilled teohnioians in multiple domains.

(1) IF-THEN produotion rules

IF-THEN produotion rule formalisms are as follows:

$$\text{IF } (R_1 \text{ AND } R_2 \text{ AND} \ldots \text{AND } R_q) \text{ THEN } (CR) \text{ CF } (w) \qquad \ldots\ldots\ldots\ldots(1)$$

$$R_i = CN_l \text{ OR } CN_{l+1} \text{ OR} \ldots \text{OR } CN_k$$
$$(i=1,2,\ldots,q;\ l,k \in \{1,2,\ldots,n\};\ \text{and } l \le k) \qquad \ldots\ldots\ldots\ldots(2)$$

Where CN_1, CN_2,..., CN_n represent rule oonditions; CR represents rule conclusion; CF represents the remark of oonfidenoe faotor of the rule; w represents the value of the rule's confidenoe faotor and $w \in [0,1]$; $n \le 10$.

This soheme is used to represent the knowledge and expertise that human experts use to work in speoial domains. Moreover, w makes the desoription of expert knowledge more practioal.

(2) Frame-based struotures

Frame-based structures are used to desoribe deolarative knowledge of conoepts, struotures, and function models. They use a group of embedded attributes and relevant values to represent a complex entity, so these schemes oan be used to represent the general struotures of oomplex objeots.

(3) Prooedures

In the prooesses of knowledge reasoning, some calculations are needed. Generally, these complex caloulations oorrespond to the statement sequences of some procedural language (for example, FORTRAN). For the oonvenience of calling, we give each sequenoe a definite name as its abbreviation. In this system, we oall the sequenoes (for example, standard algorithms in AB) as prooedures. In knowledge reasoning, oalling abbreviations are called prooedures oalling.

3.2. Certainty reasoning

In ESSBDSS, let $w=1$, then the system can implement oertainty reasoning according to the following definitions:

Definition 1. Assume that $k=l$, $R_i=CN_l$, $l \in \{1,2,\ldots,n\}$, then only if all of R_i are T(ure), CR is T; otherwise, CR is F(alse).

Definition 2. Assume that $q=1$, $R_i=R_1=R=CN_l$ OR CN_{l+1} OR...OR CN_k, ($l,k \in \{1,2,\ldots,n\}$, and $l \le k$), then only if all of CN_m ($m \in \{l,l+1,\ldots,k\}$)

are F, CR is F; otherwise, CR is T.

Definition 3. Define the reasoning order: OR > AND.

3.3. Uncertainty reasoning

There are several methods to process uncertainty. The representative methods are Mathematical Theory of Evidence (Shafer (1976)), Theory of Possibility (Zadeh (1978)), Subjective Bayesian Methods (Duda et al. (1976)), Theory of Certainty (Shortliffe et al. (1975)), and Incidence Calculus (Bundy (1984)). This ESSBDSS uses CF method and fuzzy reasoning to implement uncertainty reasoning.

(1) CF method. CF method is an improved method of Theory of Certainty. Assume that $CF(CN_1),\ldots,CF(CN_n)$ respectively indicate confidence factor of $CN_1,\ldots CN_n$; $CF(CR)$ indicates confidence factor of reasoning conclusion. Then:

a. If $l=k$, $R_i=CN_l$, $l\in\{1,2,\ldots,n\}$, then

$$CF(CR) = \min\{CF(R_1),\ CF(R_2),\ \ldots,\ CF(R_q)\}*w \qquad \ldots\ldots\ldots\ldots\ldots(3)$$

b. If $q=1$, $R_i=R=CN_l$ OR CN_{l+1} OR ... OR CN_k, ($l,k\in\{1,\ldots,n\}$, $l\leq k$), then

$$CF(CR) = \left[\sum_{i=1}^{k} CF(CN_i) - \prod_{i=1}^{k} CF(CN_i)\right]*w \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

c. If $l\leq k$, and $q>1$, then formula (3) and (4) are used together.

(2) Fuzzy reasoning. In views of difficulty to determine the value of confidence factor, the ESSBDSS can combine fuzzy linguistic variables (for example, 'definite', 'more or less', 'possible', etc.) with corresponding rules to give corresponding values of confidence factors of the rules. Uncertainty of evidences can be solved by checking the table of subordinate degree.

Certainly, we can put other reasoning methods (for example, nonmonotonic reasoning, theory of evidence, ect.) into the system continuously to adapt the needs of uncertainty reasoning of different models.

3.4. Complex problems solving

In ESSBDSS, under the control of meta-level knowledge, the system makes inference to domain KB using domain reasoning engine and divides the complex problem into subproblems, and then assigns them to multiple ESs. Multiple ESs. Multiple ESs can solve their respective subproblems and make their subdecisions. Finally, these subdecisions will be coordinated by the decision makers, untill a whole and consistent decision is formed.

3.5. Subdecisions coordinating

This system can provide several algorithms to coordinate the subdecisions from multiple ESs. These algorithms are optimal overall method (OOM), majority vote method (MVM), predicate overall method (POM), procedure overall method (PRO) and threshold method (THM).

4. Algorithm of Implementation for Solving Large-Scale Decision Problems

This system can be used in large-scale decision making processes. The algorithm to implement the above functions are as follows:

Step 1. Problem decomposing

Under the control of meta-level knowledge, the system decomposes the problem P into many subproblems $(P_1, \ldots, P_m)$ and each of them can be solved by single ES.

Step 2. Subproblems classification

Definition 4. Let V be a set, if p is a kind of classification which can be used to divide V into n subsets $V_1, \ldots, V_n$, and

$$\bigcup_{i=1}^{n} V_i = V, \quad V_i \cap V_j = \Phi, \; i \neq j, \quad (i, j \in \{1, 2, \ldots, n\})$$

then p is called a kind of classification to V. And the set of V under p is noted as: $V/p = \{V_1, \ldots, V_n\}$.

According to the definition 4, $P = \{P_1, \ldots, P_m\}$ is divided into $GP_1, \ldots, GP_n$ under the classification p, where GP_i is a subset (for example, $GP_2 = \{P_3\}$; $GP_5 = \{P_1, P_5\}$; etc.) which is also called task i.

Step 3. Tasks assigning

Let $N(GP_i)$ be the number of subproblems in GP_i, $N(GP_i) \in [0, m]$, here GP_i corresponds to ES_i.

If $N(GP_i) > 0$, then task i is assigned to ES_i.

Step 4. Reasoning engines and KBs choosing

Some ESs that accept tasks choose their KB and E:

Choosing KB: KB (<Num>); <Num>::= integer | letter.

Choosing E : E (<Num>); <Num>::= integer | letter.

Step 5. Link of KB, MB, AB, and DB

(1) E_i makes inference to Task i using KB_i ;

(2) Task i puts input parameters from DB to File j corresponding to the Procedure j ;

(3) Task i asks MBMS to call the Procedure j ;

(4) MBMS calls the Procedure j from MB ;

(5) MB calls the sequencee of standard programs from AB ;

(6) Run the Procedure j, and the parameters are sent back File j; RETURN;

(7) Task i acquires the results from File j; CONTINUE.

Note that the reasoning control strategies are as follows:

RCS (<Strategy>); <Strategy>::= ROS | IFS | NKF | RCS | UGS .

Where ROS, IFS, NKF, RCS and UGS respectively indicate rule order, importance-first, new knowledge-first, random choosing, and user given strategy.

Step 6. Each ES write its reasoning result (subdecision) on the blackboard, then the whole decision is:

$$S = (S_u , S_v , \ldots , S_w) , \quad (u,v, \ldots ,w \in \{1,2, \ldots ,n\}) .$$

Step 7. Decision coordinating

DCA <Algorithm><Task-list> ; <Algorithm>::= OOM | MVM | POM | PRO | THM .

If the decision makers are satisfied with the decision S, then

$S^* = (S^*_u , S^*_v , \ldots , S^*_w)$; END . ELSE choose another algorithm to coordinate the subdecisions or GOTO Step 5.

5. Summary and Conclusions

ESSBDSS is a result of the development of DSS, ES, distributed problem solving or distributed artificial intelligence (DPS or DAI), including many disciplines and fields. Within this paper, the structure and functions of ESSBDSS , and its applications in large-scale decision making processes are presented. However, much work remains to be done, including the following:

(1) Automatic knowledge acquisition from multiple experts.

(2) Algorithms that allow conflict coordinating among multiple ESs to be implemented conveniently in practice must be developed.

(3) Knowledge organization and cooperation of multiple ESs.

(4) Extensive simulation studies are necessary to evaluate and calibrate the performance of the ESSBDSS in large-scale decision making processes.

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