MODEL EXPERT SYSTEM MES

Guan Jiwen , Xu Ying
Department of Computer Science
Jilin University
Changchun, P.R.C.

Chang Minche , Zhao Jizhi
Well Logging Campany
Daqing Petroleum Administrative Bureau
Daqing, P.R.C.

ABSTRACT

The comprehensive oil log interpretation is a procedure of numerical calculation and logical (or plausible) inference. In other words, the results of preliminary inference will provide a basis for the choice of parameters of calculation formula, and then the results of numerical calculation will be used as evidences for further inference, and so on and so forth. In view of this situation, we have designed a model expert system (tool system) MES and established a comprehensive oil log interpretation expert system WELIES based on the system MES.

In MES, we introduced the concept of "TASK" to make numerical calculation intergrated with logical(or plausible) inference during the task solution. The execution of MES is a procedure of task solution. Ways of solving a task are defined by Task Transformation Rules.

The Knowledge Representation is divided into two parts: 1) Task Transformation Rules, including Task Decomposition Rules and Task Derivation Rules; 2) Inference Rules, including Production Rules and Procedure Rules.

We adopt Dempster/Shafer's Evidence Theory [6] to express uncertainty.

INTRODUCTION

Rule-based expert system has come into wide application since the 70's [3]. Developments of MYCIN [1] ,PROSPECTOR [2], DIPMETER ADVISOR [4] [5] and other well-known expert systems have become the foundation for the development of pragmatic expert systems. These systems, whether colleting data from users in the interactive way or from some on-line instruments, emphasize only logical(or plausible) inference. However, in many applied fields, for instance in the field of oil log interpretation, the procedure that experts use to solve problems is as follows: analyzing various preliminary information(qualitative interpretation) and then determining the parameter values needed by further quantative interpretation and then calculating using theoretical or empirical formula and then analyzing qualitatively further the results of calculations and so on and so forth. We hope to establish a uniform framework to deal with numerical calculation and logical (or plausible) inference without impairing the advantages of the Rule-based system.

We began to develop a comprehensive oil log interpretation expert system in the March 1984. We have designed a model expert system(or tool system) MES and a comprehensive oil log interpretation expert system WELIES based on MES.

This paper will not attempt to explain the comprehensive oil log interpretation expert system WELIES in detail, but we will use it as an example to explain the system MES.

One version of MES and the system WELIES are implemented on PERKIN-ELMER 3220 in FORTRAN 7.

I KNOWLEDGE REPRESENTATION

<u>Definition</u>: (?X, OBJECT, VALUE, SUPPORT, PLAUSIBILITY) is called an ASSERTION.

Where, in WELIES, ?X is the name of some physical information or conclusion; VALUE is the value of the OBJECT; SUPPORT is a measurement of how evidences support the VALUE of the OBJECT; PLAUSIBILITY is a measurement of how evidences do not oppose the VALUE of the OBJECT. We will explain these two concepts later.

<u>Definition</u>: T=(TN,?TV) is called a TASK, where TN is the name of a TASK, ?TV is the value of a TASK. ?TV gets value from { 'TRUE' ,'FALSE'} .

In MES, there is a task name for every OBJECT, respectively.

A TASK is set whenever a task name is provided to the TASK Solution Program. In the following, a task solution of our definition means a procedure to evaluate a TASK. A task solution is finished when the TASK has a value.

For every TASK T=(TN,?TV), ?TV=TRUE' means that the solution for the TASK succeeds, and ?TV= 'FALSE' means that the solution for the TASK fails. We will explain these in detail in the Sec.IV.

Ways to solve a TASK are defined by Task Transformation Rules.

(I) Task Transformation Rules

Task Transformation Rules include Task Decomposition Rules and Task Derivation Rules.

Definition: Let T=(TN,?TV) a TASK, we call
$T \rightarrow T1 \wedge T2 \wedge \cdots \wedge Th$
a Task Decomposition Rule, where Ti=(TiN,?TiV), $1 \leq i \leq h$.

The function of Task Decomposition Rules is to transform a TASK into some subTASKs and define the way to evaluate the TASK.

Definition: Let T=(TN,?TV) a Task, we call
$T \rightarrow T1, T2, \cdots, Th$
a Task Derivation Rule, where Ti=(TiN,?TiV), $1 \leq i \leq h$.

The function of Task Derivation Rules is to arrange the order of solutions for TASKs.

Left-handed parts and right-handed parts of the Decomposition Rules have some logical relations, but left-handed parts and right-handed parts of Derivation Rules do not necessarily have logical relations, but contain sequence relation.

At this point, we only give the syntax of the Task Transformation Rules. Meanings of them will be given in the Sec. IV.

(II) Inference Rules

There are two kinds of Inference Rules in the MES: 1) Production Rules, 2) Procedure Rules.

Definition: Syntax of a Production Rule is:
(?X,OBJECT,PREDICATE,VALUE)$\chi \cdots \chi$(?X,OBJECT,PREDICATE,VALUE) $\rightarrow$ (?X,OBJECT,VALUE,CERTAINTY)$\wedge \cdots \wedge$ (?X,OBJECT,VALUE,CERTAINTY).

Definition: Syntax of a Procedure Rule in MES is:
(?X,OBJECT,?VALUE),$\cdots$,(?X,OBJECT,?VALUE) $\rightarrow$ (?X,OBJECT,SUBROUTINE NAME,?CERTAINTY).

We will give the definition of CERTAINTY in the Sec. II.

In our opinion, the function of Production Rules is to bind values to some OBJECTS. In this view, we have developed the concept of RULE to include Procedure as a kind of RULE. In the above definition of a Procedure Rule, OBJECT, in every item of the condition part, is a name of a parameter needed by the SUBROUTINE whose name is given in the action part. OBJECT in the action part is the name that the SUBROUTINE will bind value to. Procedure Rule can be used only backward. ?VALUE in the condition part is empty. It will be bound a value only when needed.

II REPRESENTATION OF UNCERTAINTY

Let $S=\{s1,s2,\cdots,sn\}$.

Definition: m is a primary support function on 2^S, if
(1) $0 \leq m(A) \leq 1$, for $A \subset S$,
(2) $m(\phi)=0$,
(3) $\sum_{A \subseteq S} m(A)=1$.

In WELIES, we especially have m(A)=0, for $A \neq S \wedge A \neq \{si\}$, $1 \leq i \leq n$.
For simplicity, we denote m(si) for m({si}). So, in WELIES, we change the form of the definition into:

Definition*: m is a primary support function on S, if
(1) $0 \leq m(si)$, for $1 \leq i \leq n$,
(2) $\sum_{1 \leq i \leq n} m(si) \leq 1$.
And we define $m(S)=1-\sum_{1 \leq i \leq n} m(si)$. We will consider only m(si) in the following.

Let m1 and m2 functions meeting the definition of primary support function, and m1(si)=ai, for $1 \leq i \leq n$, m2(si)=bi, $1 \leq i \leq n$, $m1(S)=\theta 1$, $m2(S)=\theta 2$.
We define operator $\oplus$:
Definition: We define $m=m1 \oplus m2$, and let m(si) =ci and ci=di/p, where $di=ai*bi+ai*\theta 2+\theta 1*bi$, and $p=\theta 1*\theta 2+\sum_{1 \leq i \leq n} di$.

Obviously, m meets the definition of primary support function and $\oplus$ is both associative and commutative.
In fact, the above function is a simplified form of the Combination of Evidence formula of Dempster/Shafer's Evidence Theory [6] under the condition of m(A)=0, for $A \neq S \wedge A \neq \{si\}$, $1 \leq i \leq n$.

Definition: We define SUPPORT function as $Bl(A)=\sum_{a \in A} m(a)$ and PLAUSIBILITY function as $Pl(A)=1-\sum_{a \notin S} m(a)+\sum_{b \in A} m(b)$, $A \subset S$.
Obviously, $Pl(A) \geq Bl(A)$, $A \subset S$.
In MES, uncertainty with conclusion is represented with (Bl,Pl).
We now come to the definition of the CERTAINTY of the condition part of an Inference Rule:
Definition: CERTAINTY of an item in the condition part of a Production Rule is defined as:
match degree*f(SUPPORT of corresponding ASSERTION in the Database, PLAUSIBILITY of corresponding ASSERTION in Database), where match degree is defined as follows: (1) if the value of the OBJECT in the item is a symbol, match degree= $\begin{cases} 1, & \text{match} \\ 0, & \text{otherwise} \end{cases}$
(2) if the value of the OBJECT in the item is a number, the system WELIES has defined Match function for every predicate (e.g. GE,IN,and so on).

Definition: CERTAINTY of the condition part of a Production Rule is defined as the value obtained by using the following rules repeatedly:
(1) if there is only one item inthe condition part of the Rule, CERTAINTY of the item is the result needed;
(2) use a new item to replace the items connected with $\wedge$,and CERTAINTY of the new item is the minimum of all CERTAINTYs of the items connected with$\wedge$;
(3) use a new item to replace the items connected with $\vee$,and CERTAINTY of the new item is the maximum of all CERTAINTYs of the items connected with$\vee$.

Definition: CERTAINTY of the condition part of a Procedure Rule is defined as the minimum of all SUPPORT values of the ASSERTIONs corresponding to the items in the condition part.

A Rule will not be invocated if its CERTAINTY of the condition part is less than a fixed threshhold.

CERTAINTY of every item in the action part of a Production Rule is defined dynamically by a function s(CERTAINTY of the condition part, static CERTAINTY of this item). CERTAINTY of the action part of a Procedure Rule is defined as the CERTAINTY of the condition part.

III MAIN PARTS OF MES

MES is mainly composed of:
1) Task Solution Program
2) Explanation Program
3) Subroutine Base and its Management Program
4) Rule Knowledge Base and its Management Program
5) Comprehensive Data Base and its management Program

In WELIES, the Subroutine Base is composed of standardized well-log interpretation software. Any program in the Base has no argument. The beginning parts of all these programs are communication blocks communicating with Comprehensive Data Base Management Program to get parameter values needed.

IV TASK SOLUTION

Execution of the system MES is driven by task solution, and Task Transformation Rules define the ways of solving TASKs.

Definition: A TASK T gets 'TRUE', if and only if : (1) the OBJECT corresponding to the TASK T has a value with strong support, or (2) the decomposed subTASKs TI,T2/",Tk of the TASK T all have values and at least one has a value 'TRUE' ;
a TASK T gets a 'FALSE', if and only if: (1) the OBJECT corresponding to the TASK T has some special value indicating contradiction or mistake, or (2) all the decomposed subTASKs T1,T2,*-' ,Tk of the TASK T have values 'FALSE'.

Ways of solving a TASK T imply the ways of evaluating the OBJECT corresponding to the TASK T. The procedure of evaluating an OBJECT, i.e., a procedure to produce a new ASSERTION happens simutaneously with the procedure of solving a TASK.We call the procedure the "side effect" of the Task Solution.

Every OBJECT has a field of value from which it may get values. This field does not include all values indicating contradictions and mistakes. The OBJECT corresponding to a TASK has the same field of value as all OBJECTS corresponding to all the TASK'S decomposed subTASKs.

The procedure of evaluating an OBJECT(except for the OBJECTS with number values) is a procedure of evaluating the uncertainty of every member in the field of value.

The procedure is as follows: 1) evaluating with Inference Rules: the CERTAINTY of an item in the action part will be used to define the primary support value m of the corresponding member in the field of value. Primary support value of a member is defined as 0 if the member has no corresponding items in the action part of an Inference Rules; 2) evaluating with Task Transformation Rules: if all decomposed subTASKs of the TASK corresponding to the OBJECT have values and are not all [1] FALSE', let mil,mi2,"-,mik, the primary support functions on the field of value respectively of all the decomposed subTASKs with values 'TRUE',and m the primary support function on the field of value of the OBJECT, we define $m=m_{i1}\oplus m_{i2}\oplus\cdots\oplus m_{ik}$.

We will now take the system WELIES as an example to describe roughly how the system MES solves a TASK: (1) users put the reqirements of what they want the system to do and set a general TASK; (2) when a TASK has an unused Task Transformation Rule, use the Rule and produce new TASKs; Derivation Rules have higher priorities than Decomposed Rules; (3) when all decomposed subTASKs of a TASK have values, evaluate the TASK and do "side effect-; (4) when the OBJECT corresponding to a TASK has a value with strong support, evaluate the TASK; (5) if a TASK is finished, and the OBJECT corresponding to the TASK has unused Inference Rules that can be used fordward, use the Rules; (6) when a TASK has no unused Task Transformation Rules and the correponding OBJECT has no values with strong enough support, find all Inference Rules of the OBJECT that can be used backward, use them; (7) if some items in the condition part of an Inference Rule has no corresponding ASSERTION in the Data Base, set a new TASK to get the ASSERTION needed; (8) when the condition part of a Production Rule has a big enough CERTAINTY, use the Rule; (9) when the condition part of a Procedure Rule has a big enough CERTAINTY, call the subroutine through Subroutine Base Management Program; (10) the use of an Inference Rule produces new ASSERTIONS and the system will store them into Data Base; (11) use 2-10 repeatedly until the general TASK is finished.

V CONCLUSION

This paper introduced the model expert system MES. We have intergrated numerical calculation with logical inference in a uniform framework in WELIES based on MES. We plan to establish some other oil expert systems based on the system MES.

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