GENERAL STRUCTURE OF OBPES SHELL SYSTEM ①

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ABSTRACT OBPES(Ore Beneficiability Prediction Expert System) shell system is a construction tool for expert systems in the field of ore beneficiability prediction, which is developed on Microsoft Windows platform using C++ language. The structure, working principle and the knowledge base, as well as knowledge learning and inference engine of OBPES shell system were described in this paper.

Key words OBPES shell system knowledge base knowledge learning inference engine

1 INTRODUCTION

The research on ore beneficiability, which determines product scheme, separation method, technological flowsheet, technological condition and metallurgical results, is a basic and necessary work in mineral industries. It is also a miscellaneous work which requires a lot of manpower, material resources and time.

The ore beneficiability prediction expert system (OBPES) of Pb-Zn ore[1] developed by the authors is able to predict the beneficiability of lead and zinc sulfide ore by use of mineralogy process, applied mathematics, artificial intelligence and computer techniques. There are some hundred kinds of nonferrous metals, ferrous metals, rare metals and nonmetallic ore deposits in China. If OBPESs corresponding to these ore deposits are established, both economic and social benefits will be inestimable.

Establishment of OBPES for every kind of ore from the beginning consumes a considerable manpower, material resources and time. For this reason, a developing tool of OBPES for all kinds of ore—OBPES shell system has been studied, which can simplify the procedures of building OBPES of different kinds of ores. From analysis of solving steps for ore beneficiability prediction problem, it can be seen that the predicting procedures for any kinds of ores are very similar, so it is feasible to build OBPES shell system for new OBPES of other kinds of ores.

2 SYSTEM STRUCTURE AND WORKING PRINCIPLE

2.1 System structure

The OBPES shell system consists of four parts: knowledge base (KB), inference engine, user interface and application utilities. The system written by C++[2] and Prolog language on Windows platform can be performed on microcomputers senior to 386. Its structure is shown in Fig. 1.

The KB part includes KB construction, management, organization and maintenance. Users can select suitable methods from the knowledge representation methods provided by the system according to the characteristics of the domain knowledge. The shell system has a superior knowledge input system, which can find errors happening when users input knowledge and examine the consistence and redundancy of the input knowledge. The KB part also has such functions as addition, deletion, edition and copy of knowledge.

The inference engine processes the knowledge in KB and determines the current state and strategy taken in the next step. Users can select different kinds of inference mechanisms, such as

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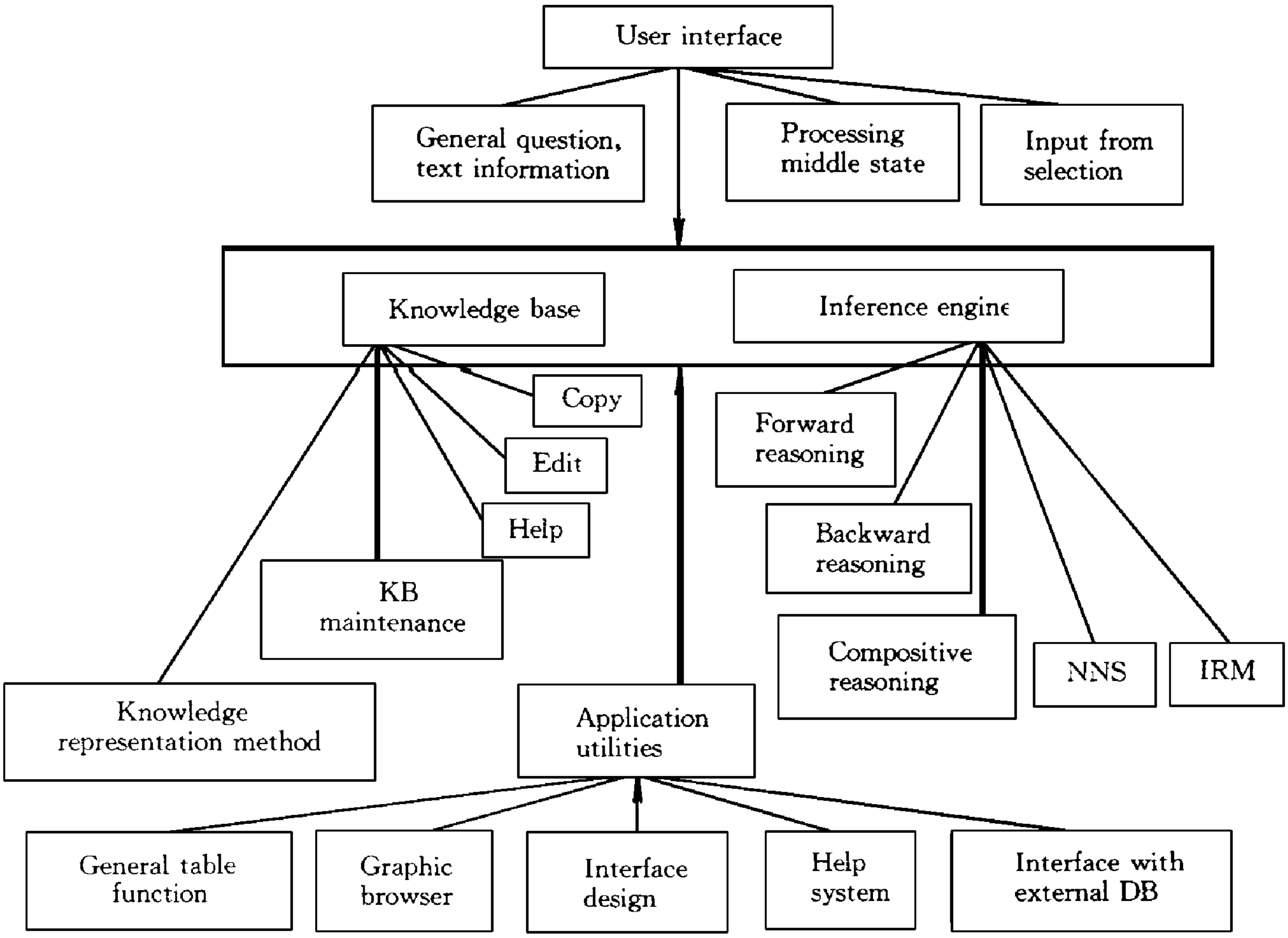

Fig. 1 Structure of OBPES shell system

forward reasoning, backward reasoning, compositive reasoning, neural network simulation (NNS) reasoning and other kinds of inexact reasoning methods(IRM).

Users exchange with the shell system through the user interface. The present ES(expert system) is browsed, executed or traced partly by the user interface. UI(user interface) displays the general questions, explanations and text information, and provides processing to the middle state of KB.

Some tools needed in building ES are provided by application utilities. The inference chains formed in inference process are displayed on graphic browser. The prediction data are transported to printer in the form of table by the general table function. Users can guide directions of searching and problem solving to make inference go on along the direction expected. The design tool helps users to design interfaces for new ES, including different kinds of windows, menus, dialog frames, clickbuttons, graphics, etc.. The help function helps users to learn the use method of the shell system as quickly as possible. The interface with external database provides communication means between ES and external database.

2.2 Working principle

OBPES shell system is used to provide overall architecture, KB building tool, inference mechanism selection, interface formation utility and other practical tools (such as debug tool, graphic tool, general table design tool, executing external procedures, etc.) for the construction of OBPES for given ores.

The steps to use OBPES shell system are as below:

(1) Collecting, analyzing and inducing the domain knowledge of beneficiability prediction of a certain ore, selecting knowledge representation method, determining KB structure and building

the KB;

(2) Selecting the inference mechanism, applying the graphic browsers to trace the reasoning process, and consummating the KB and inference engine continuously;

(3) Designing the interface including Windows, menus, click buttons and dialog frames by use of interface design tool;

(4) Improving the interpreter and help functions of the ES;

(5) Combining various functions with menus and click buttons on the interface to make up preliminary ES;

(6) Using the application utilities of the shell system to test the newly-built ES and consummate it continuously.

3 MAIN COMPONENTS

3.1 Knowledge base

The KB of this system consists of facts, frames and calculating models. The facts include classification fact, descriptive fact and explanation fact, etc.. The combination of the rule and frame is able to represent the hierarchy of knowledge. The calculating models are represented by frames and models. The models can be activated and executed by inquiry operations controlled by meta-rule, and can be executed when inexact reasoning is conducted using subordinate functions. The hierarchy structure of objects is the core of the system's knowledge base. And it is the knowledge source, the area of work and storage and the sets of problem solving units. The system expresses the conceptions and substances involved in the problem solving as objects (classes and instances), as shown in Fig. 2.

The methods and knowledge of each object are encapsulated in itself. The object identifier includes object name, class name, superclass name, type, variable name and interface of message transferring. Relevant attributes of an object are recorded in each slot of the object, the operations of which in "method", and the rules in "rule". The contents of both slot and method have the property of inheritance. The system adopts the method of multi-inheritance, which means that an object can have several superclasses. Adopting multi-inheritance can improve message-sharing further.

Each knowledge object has the encapsulation property. Users can neither modify the internal state of an object directly nor execute the internal knowledge processing functions directly. The following is an example of a knowledge object:

Object identifier	Types
Object name: flotation	Character
Superclass name: separation method	Character
Variables: stage number of grinding-flotation,	Number
cycle number,	Number
cleaning and scavenging number,	Number
sequence of flotation.	Character

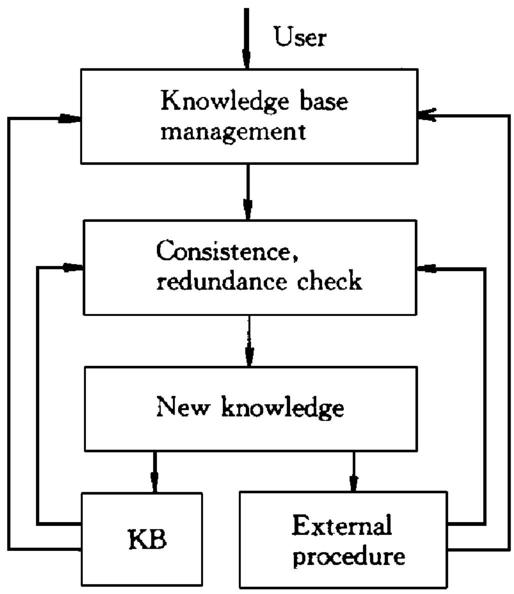

Fig. 2 Hierarchy structure of objects

Knowledge:
flotation plant name:
plant address:
ore deposit type:
plant scale:
mineral type:
Knowledge processing methods:
Prediction rule 1: IF [Cu, Pb, Zn ore] THEN [flotation]
Prediction rule 2: IF [single metal, coarse disseminated ore]

THEN [one stage, one circuit flotation]

Prediction rule 3: IF [single metal, non-uniform disseminated ore]
THEN [tail-regrinding, two or three stage flotation]

Prediction rule 4: IF [high content of valuable mineral, low requirement of concentrate quality]
THEN [rougher concentrate]

⋮ ⋮

Knowledge acquisition 1: asking about mineral composition, grades of valuable minerals in run-of-mine ore and oxidation rate

Knowledge acquisition 2: asking about the dissemination size, dissemination characteristics and associated relationship of valuable minerals in run-of-mine ore

Knowledge acquisition 3: asking about ore texture, product kinds, etc.

⋮ ⋮

Methods in objects can only be started through message transferring between the objects. The concerning methods include not only rule reasoning, but also other solving functions such as visiting to external database, neural net simulation and user defined procedure. Because of encapsulation property of the object, various kinds of solving operations will not disturb each other.

3.2 Knowledge acquisition

Knowledge learning engine can realize artificial knowledge acquisition. When users input knowledge concluded as rules and frames into KB, all relative rules and frames will be shown by the system. These rules and frames can be deleted or modified by users after analyses. The structure of knowledge learning engine is depicted in Fig. 3.

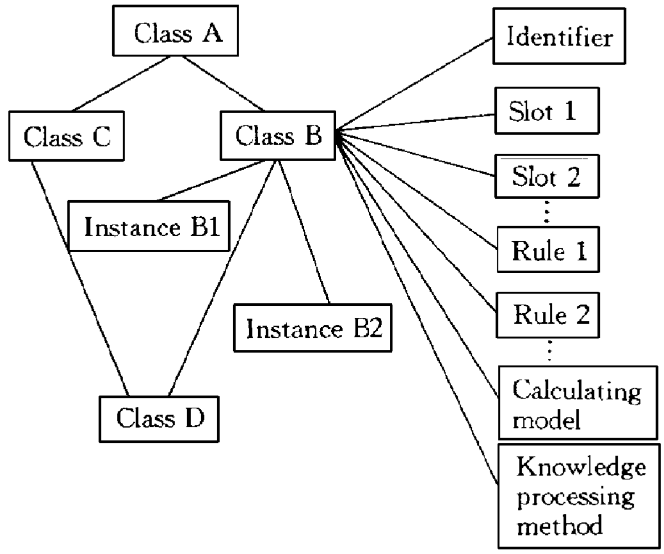

Fig. 3 Structure of knowledge learning engine

Learning based on explanation is adopted in the system. After every successful reasoning the valid reasoning route would be recorded. When similar conditions appear next time, the inference engine would find the knowledge quickly in terms of the routes recorded. This is a kind of control knowledge which improves the reasoning efficiency of inference engine.

Knowledge automatic learning is realized by neural net technology. The neural net can adjust automatically the connecting weight between neurons during learning. The knowledge obtained is distributed and saved in the whole network so as to realize the automatic learning function of neural network.

3.3 Inference mechanism

The inference mechanism of the system is encapsulated in each knowledge class. Various kinds of inference mechanisms (such as inexact reasoning, neural net simulation, etc.) are executed through characteristic inheritance and message transferring. If the required conditions are not satisfied in the object, knowledge processing method can still be asked for from fatherclass or grandfatherclass or even higher classes till the satisfactory knowledge is obtained. Message transferring is used to acquire knowledge between objects through data-driven style.

Knowledge and knowledge processing methods are packed in knowledge objects, so an object can be used to describe and solve an independent sub-question. Various kinds of reasoning methods of production system are used in objects.

The inference procedure of the system acts as a procedure of deriving new objects. It consists of matching related basic classes according to the fact characteristic of the problem being solved, deriving objects from basic class, acquiring knowledge through characteristic fill, inheritance, inference and procedure executing, as well as establishing new objects. The last new objects are just the answer of the problem.

4 TECHNICAL INDEXES

An ES shell system's technical indexes should include validity of system, redundance of inference procedure, performance of interface, stability, low cost and complete functions of the system. The validity of the system refers to the quality of its decisions and suggestions and needs to be verified in the practice. The interface of OBPES shell system is Windows graphic interface of high friendly level. The complete functions of the system include basic parts of shell system (knowledge base construction, inference mechanism, knowledge learning, etc.) and various kinds of debug tools, trace tools, graphic tools for users. The system cost is decided by cost of software, hardware, manpower, and time. The cost of our system is low, and the stability of OBPES shell system will be consummated continuously in practice.

5 CONCLUSION

The feasibility of OBPES shell system was analyzed. The structure of the system, the main function of each parts, the working principle and the application steps were discussed in the paper.

The KB based on the object is used by the system. Automatic knowledge acquisition includes learning based on explanation and neural network learning. The inference mechanism is encapsulated in knowledge class through characteristic inheritance and message transferring. The OBPES shell system has complete functions and friendly interface. The system will be tested, verified and consummated continuously in the practice of ore beneficiability field.

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