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APPLICATION OF EXPERT SYSTEMS IN LAND RESOURCES RESEARCH

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ABSTRACT. *By means of remote sensing and GIS to research loess physical conditions of Loess Plateau in China, an expert system of land suitabiliy evaluation in loess hilly area as a studying model, has been built for rational land use. Based upon having built a database and knowledge base of physical geographic attributions of the land resources, the expert system can inference and produce a land suitable evaluation map automatically, so as to make land planning by reasoning network. The system has also interpretation function and knowledge maintenance function.*

INTRODUCTION

Land is the condition on which human beings depend for living. It is one of the precious resources. "Cherish an inch of land and use it reasonably" has been a basic policy of China.

At present, the requirement of land for agriculture and other purposes is growing gradually and due to unreasonable land use, the environment is becoming worse increasingly. It is necessary that we use land reasonably and keep the land resources steady forever as land resources are limited. The purpose of the land evaluation is to let people know clearly the relationship between situation and usage of land resources, and to supply the possible choices of different land uses and land prospects to the government (Xianme, 1981). So far, techniques and methods of land evaluation have been improved greatly. Remote sensing which has provided a great deal of information for the management of land resources has been applied to the investigation of land resources. At the same time the requisition of modern agriculture for land evaluation is growing higher in level, content and timely demand. It needs us urgently to use computer aided evaluation systems to help land planners to make decisions (Xingyuan, 1986).

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Geographic Information Systems (GIS) have developed for more than 20 years, and we have obtained many successful experiences. Nowdays GIS is playing an important role in different fields. It is used in land management, which is called Land Information Systems. It provides a good tool for research, reasonable development and scientific management of land resources (Robinson, Frank, & Blaze, 1986).

However, in a sense, because of lacking the support of the special knowledge, a number of GIS works inefficiently in using a large amount of data in system now. For bringing GIS into full playing, it is necessary to combine the achievements of resources research, introduce artificial intelligent techniques in the fields, and establish a relevant knowledge processing system. By organizing a flexible database and knowledge base, we could solve the problems — which are difficult to solve by means of traditional data processing — with ease. From the point of the expert, system will be more efficient in solving many geographic problems. Expert system is a kind of program system which includes a large amount of special knowledge. It uses artificial intelligent techniques to infer, depending on the special knowledge provided by one expert or several ones, simulate the thinking process of the experts in solving the problems for solving the real complicated problems, and provide the solution in expert's level. The expert system has been used in many fields since the middle of 1960s (Nilsson, 1980; Barr & Feigenbaum, 1982; Robinson et al., 1986; Ripple & Ulshoefer, 1987; Robinson, 1987).

Land Evaluation Expert System (LEES) in this paper is prepared to be applied in the loess hilly area which is the part of the northwest of China. The purposes of LEES are to propose land resource suitability evaluation, landuse suggestion and land improving and harnessing measures. It may be an efficient tool for land planner and agriculture producers in their decision-making.

MODEL OF LEES

Land quality is affected by multielements and multivariates, the selection of the factors of land evaluation is determined by the purpose of land evaluation. In evaluating a regional land, we should choose the factors which affect greatly the land quality and change more notably in the region to act as quality indexes of the land (Xianme, 1981).

In loess hilly area, the human beings reclaiming and cultivating is beyond the load-bearing capacity of the land, and the eco-environment has been deteriorated increasingly. So the aims of the land evaluation of loess hilly area are to stress developing agricuture, forestry and animal husbandry with the local conditions, to adjust land management, to prevent soil and water from running off, to harness and utilize comprehensively. Combining with the characters of the loess, the land evaluation expert provide two following principles:

1. The Ecological Principle — The measure criterion is the ecological efficiency in land use, that is, land use doesn't result in land quality degeneration.
2. The Economic Principle — Natural productive force of land resources is regarded as evaluation standards, that is, land evaluation should reflect the productive force of the land resources.

Productive capability of agriculture in loess hilly area is limited by terrain, soil erosion, aridity, elevation and soil types, etc. According to the principles advanced, those factors are regarded as limited ones. With the level and intensity of the action to grade them, we evaluate land resources by adopting the method of limited factor.

LEES is designed and completed in accordance with the model mentioned and principle of general expert system. As land has three-dimension spatial attribution, LEES involves a large number of spatial data in reasoning process. This is the different point of LEES from general expert system, LEES must be supported by GIS. Actually, the reasoning process of LEES must make use of rules of knowledge base to manipulate the data of GIS.

Constructing LEES consults the building method of some practical expert systems, such as MYCIN, PROSPECTOR. LEES uses modular programming technique, including six modulars (see Figure 1): database, knowledge base, inference machine, knowledge maintenance, interpretation and man-machine interface.

1. Database that is supported by Loess Plateau Information System (LPIS) include spatial data and economic statistical data of land resources (Jianbang, Jiangkang, Du, & Ke, 1988).
2. Knowledge base contains rules of land evaluation model.
3. Inference machine leads the system to match data, facts and rules.
4. Knowledge maintenance is a mechanism of learning. Experts and users can modify and complete rules of knowledge base according to real conditions.
5. Interpretation checks up the line of reasoning of LEES, displays the process of reasoning and explanations of land evaluation domain.
6. Man-machine interface uses menu, report and graphic displaying.

LEES adopts forward and backward rule-based reasonings. The main stages are composed of land quality classification, land use suggestion and land harnessing measures. The main part of LEES is completed in PROLOG. LEES is a microcomputer processing system which is based on IBM-PC and compatible computers.

COMPONENT AND FUNCTIONS OF LEES

Land Resources Database

Land resources database which is a part of LPIS is established with encoding, inputting, editting, format matching, transferring, reclassifying and overlaying for various kinds of geographic elements. This is the foundational work of LEES. Land resources data of LEES are of thematic map, geographic background map and digital terrain model. The first two kinds are gained by using ARC/Info system to digitize map which includes geomorphological map, soil map, soil erosion, land use map, communication and transportation map, citizen distribution map and administrative boundary map, etc. The last one is gained by digitizing terrain special line in topographic map and constructing mathematical surface.

Knowledge Base

Knowledge representation is the key to design an expert system. A suitable representation depends on the domain knowledge itself and its use.

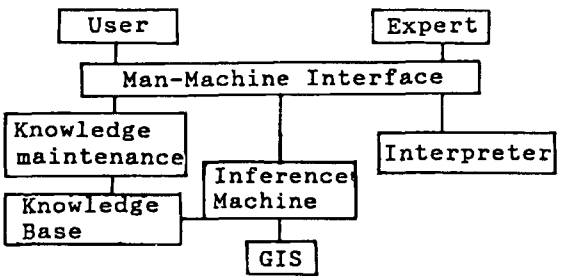

FIGURE 1. System Structure of LEES.

To select a knowledge representation of LEES, we first describe the formalization of land evaluation knowledge.

To evaluate land, the special attributions of land must be expressed. These attributions, such as terrain, soil erosion, soil class, water condition, etc. are called limited factors. Every limited factor is an independent concept of special meaning and expresses a certain descriptive knowledge. Every kind of factor of land affects agriculture, forestry and husbandry, and forms the degree of land evaluation. In order to use this land, harnessing measures must be adopted. So land harnessing measures should have a context concept, too. The conceptual knowledge is characterized with level. In the process of land evaluation, different level knowledge is used to solve the different-level problem. So the knowledge level description is the key of the knowledge level representation.

Land evaluation knowledge is composed of three levels:

1. Lower level rule (lrule): limited factor, classified factor;
2. Middle level rule (mrule): land class;
3. Upper level rule (urule): land use suggestion, the plan of land harnessing and improving.

Land evaluation knowledge can be represented by means of the following rule: IF Conditions THEN Action.

In accordance with characters and functions of hierachical knowledge, production rule form is different in different hierachical knowledge.

Lower level rule is described by means of conceptual attribution. And every character value of it has two types: (a) data of logical type and (b) data of number type.

Limited factor's attribution rule can be represented as follows:

lrule-log([parent node, node, class, annotation]);
lrule-num([parent node, node, class, level]);

including:

parent node: the factor's higher concept, i.e., backtracking status in inference;
node: every factor is acted as a node,which is factor's name;
class: a class in a factor;
annotation: literal introduction for users;
level: the number of factor.

Limited factor attribution rules describe factor's basic concept. All of the factors are conserved into a file.

Middle level rule and upper level rule are represented by

$$\text{rule premise} \rightarrow \text{rule conclusion}$$

A rule premise is a calculated value to lrules.

A rule conclusion is the result of satisfying premise rules, it may be middle conclusion or the latest goal. This reasoning is multiple level one. For example (see Figure 2):

$$R1 \leftarrow r1 \wedge r2 \wedge r3$$
$$R1 \leftarrow r1 \wedge r4 \wedge r5$$
$$Ar \leftarrow R1 \wedge r6 \wedge r7$$
$$Fr \leftarrow R1 \wedge r6 \wedge r8$$

LEES's factor rule is faced to users. The rule representation is of advantage of knowledge formalization and disadvantage of inefficient reasoning. For improving inference speed, the

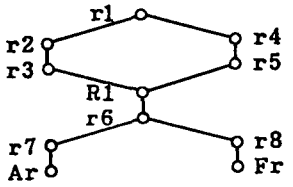

FIGURE 2. Rule of Multiple Levels.

rules are compiled rule nets in LEES before LEES reasoning. The fact that premise is concerned with it is to build rule nets according to their relationship. The rule nets are constructed:

rule-net({[parent node, node, the number of node]})

A rule net reflects an attribution of knowledge level, a net level embodies the thought of land evaluation experts. The higher level knowledge is controlled by the lower level knowledge conjunctions. It reflects restricting relation. The concerned representation method which is just mentioned above is transferred into the rule net.

The upper rule and middle rule representation are described by BNF:

<rule>::= <consequent> if <antecedent>
<consequent>::= <middle factor> | <result target>
<middle factor>::= mrule[([<item list>])]
<result target>::= urule[([<item list>])]
<antecedent>::= <condition> | <condition> | <condition>
<condition>::= predicate name[([<sub-target>])]
<predicate name>::= lrule-log | lrule-num | predicate name
<sub-target>::= parent node | node | class
<item list>::= <item> | <item list>

Inference Machine

The inference machine of LEES has been designed in two criteria:

1. Inference effect: Whether inference machine can apply knowledge to problem-solving and get the results in expert level or not.
2. Inference efficiency: Whether inference machine can complete the tasks of controlling and coordination efficiently or not.

A good inference machine can apply the domain to problem-solving correctly and efficiently. It can support the representation of domain knowledge. The selection of the representation should consider the character of problem-solving and the using way of the domain knowledge deeply.

Therefore, in building an expert system, it is necessary to design an efficient inference machine which can cooperate the domain knowledge representation with the problem.

Multiple inferences suit hierarchical knowledge to utilize the knowledge in nature and of efficiency in LEES.

The process of reasoning is composed of two parts:

1. The first-class reasoning:
   It's a forward rule-base reasoning. Inference machine collects data, matched rules, determines land class along the regular nets, that is, a course of lrule—>mrule.

2. The second-class reasoning:
   It's a backward rule-based reasoning. In accordance with land evaluation class and limited factor. Inference machine determines ways and means of land use and land harnessing. It's a course of search, backtrack and unification from lrule and mrule to urule.

By means of forward and backward reasoning, inference machine of LEES is composed of inquiring data, matching rules and determining scheme. The system gets information for current evaluation unit from land resource database or user, including all kinds of geo-elements, for example, slope, soil erosion, soil class, water condition, elevation, etc. The system matches factor's rule of knowledge base and compares with limited factor, gathers and records inquiring data and matching rules in dynamic data and holds the line of reasoning. This is the first step of the reasoning of LEES. If the limited factors in the evaluation unit exceed one which wants to have harnessing measures, inference machine will divert to the better way of harnessing measures. In the meanwhile, in accordance with the classes of land use evaluation and limited factors, the backward reasoning will compare the line of harness measures in the domain of the land use for agriculture, forestry and animal husbandry and try to determine the line of harnessing measures.

Inference machine always collects data from land resource database or user in leaf node. In other nodes, it can diagnose logical rules, compare conditions and hold out reasoning tracks.

Knowledge Base Maintenance and Interpretation

The operation of knowledge base is composed of definition, inquiry, problem solving, interpretation, addition, deletion, modification and extraction, etc.

We can add, delete and modify knowledge in the knowledge maintenance modular of LEES. The knowledge maintenance of LEES is completed by the form of man-machine interface. For the operation of lrule, the inference can be done at one time, the system diverts to the modular automatically, and inquires user what operation will be needed in the knowledge base.

After starting the inference machine, the modular of interpreter begins automatically and answers the questions to be raised in LEES and displays the line of reasoning and the using rules, etc. It can instruct the system why the inquiry is made, why user inputs information and how to get the results. Its purpose is to make users comprehend whether the line of reasoning and the results of LEES is true or false. If the user is doubtful about it, he can refuse to use it. The reliability is very important in a practical expert system.

Man-Machine Interface

1. Menu:
   The user can work with multi-level menu in LEES. The form of the menu is simple and clear.
2. Graphic displaying:
   We have designed a graphic displaying modular of multifunctions to represent land evaluation results, display a variant of geo-element spatial distributions, show the relations of factors and paths of reasoning.

CONCLUSION

Land evaluation is a special field in resources research. To use the expert system in land evaluation is a kind of technique and method. Its results in the test area of Ansai County and Yulin County of loess hilly area declared that using the expert system in land evaluation was feasible and efficient. Under the suitable conditions of knowledge representation, selection of

main factors in land evaluation and design of inference machine, the results from the land evaluation by using computer are similar to the one on-the-spot analysis by experts; however, the former is much more efficient than the traditional one. The main idea of LEES design may be useful for landuse plan, consultation of agriculture and so on.

Of course, LEES is only a primary research in the test area; it needs further study to prove its real efficiency. We are drawing this test area into the Loess Plateau.

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