THE PRINCIPLES OF GEOGRAPHICAL EXPERT SYSTEM

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ABSTRACT

As computer technologies used in geography, Geographical Information System (GIS) is developed to manage geographical data and to solve some geographical problems according to geographical models. But there are many geographical problems that cannot be defined by definite models and cannot be solved by GIS. As the combination of geography and Artificial Intelligence (AI), Geographical Expert System (GES) is designed to deal with these kinds of problems. GES is a kind of software system, which is based on geographical knowledge from geographer to deduce intelligent results. Therefore GES can deal with many geographical problems that often can only be solved by experts.


1. INTRODUCTION

Geography as a science has been on the phase of concentrating its research mainly on describing phenomena for a long time. Geographer based on predecessors working results and geographical data and descriptions got from field trips to draw a series of conclusions, and those conclusions will become experience for later geographer. Figure 1 shows the classical geographical methods.

By the end of 1960s, with the development of Remote Sensing and computer technology, geography has adopted many new research methods, which is changing geography from qualitative science to quantitative one. Now the research methods of geography has reached a new level, especially in Geographical Information System (GIS). GIS not only gains and manages geographical data from different sources, such as remote sensing images and field measured data, but also derives some new information by calculating geographical data according to geographical models. GIS now is successfully used for geographical planning and resource management, such as landuse plan urban development. On the other hand, most of geographical problems are inexact, which can not be or are very difficult expressed as definite models, for example, how to select suitable methods for the conservancy of soil and water, make an auxiliary decision of urban system, make an agricultural planning, etc. As a kind of Management Information System (MIS), GIS is not suitable to process these kinds of problems.

When to process these kinds problems, geographer use geographical knowledge and experience to reason and gain inference conclusion. Expert System (ES) use knowledge as reasoning kernel to imitate human expert reasoning and get proper results. When we use ES technology in geography, we can build Geographical Expert System (GES), which is a kind of computer system with a great deal of geographical knowledge, and can reason with these knowledge to solve inexact and undefined geographical problems.

GES is the combination of geography and Artificial Intelligence (AI), and can be defined as

GES = GIS + artificial intelligent kernel.

Supported by Remote Sensing, GIS and GES, Modern geographical methods can be shown as figure 2.

2. DESIGN OF GES

Designed to solve geographical problems by reasoning with geographical knowledge, GES put geographical knowledge at the most important position. As Geographical data is the inference source, it is the reasoning object with geographical knowledge. There are three main problems in GES, which are concerned with geographical knowledge and data, that is,
2.1 MCGIS — data acquisition and management system of MCGES

Geographical data may be defined as digits or values, graphics, images and maps etc. which express geographical information. A GIS (MCGIS) with integrative structure and completed functions is developed to acquire and manage data for MCGES. MCGIS not only can be used as an independent GIS, but also can be consistent with the main system (MCGES) as a global data base. The data structure, file format and operations in MCGIS are designed to fit with MCGES.

As a sub-system of MCGES, MCGIS has two main functions (Fig.4):

(1) Data management, that is, inputting, pre-processing, operating, managing and outputting geographical data (maps and attribute forms);

(2) Solving geographical problems with known models.

The structure of MCGES can be shown as Fig.3.
MOGIS uses Geo-Code Model (GCM) to describe geographical attributes. GCM reasonably grades geographical factors and uses symbol strings, such as digital strings and literal strings, to express geographical attributes. Every bit in those strings represents a different attribute, with its value representing the attribute value.

Vector and raster (grid) are two basic graphics data formats used in MOGIS. Vector data is mainly used to input graphics and calculate geometric data (area, length etc.), and raster data or images is mainly used to operate graphics and images. MOGIS defines two basic image operations, that is, image overlay and image extract, both of which are based on the GCM-expressed geographical attributes.

Image overlay can be expressed as
\[ I_1 + I_2 + I_3 + \ldots + I_n \rightarrow I \]

where
1. \( I_1, I_2, \ldots, I_n \) are independent geographical factor images (raster maps);
2. \( I \) is an integrative geographical factor image, which is composed of \( I_1, I_2, \ldots, I_n \).

Image extract is the reverse calculation of image overlay, which can be expressed as
\[ I \rightarrow I_1 + I_2 + I_3 + \ldots + I_n \]

that is, getting some dependent or independent geographical factors from an integrative factor.

Generating Digital Terrain Model (DTM) is another important function of MOGIS. DTM can be expressed as
\[ T_i = f_i(x, y) \]

where
1. \( T_i \) as topographical factors, such as elevation, aspect, slope etc;
2. \( f_i \) as the function of topographical factors to geographical coordinates \( (x, y) \).

MOGIS also uses a series of mathematic methods to solve geographical problems with known models. Those mathematic models include multiple regression analysis model, tendency analysis model, cluster classification model and principal component analysis model and so on.

2.2 GKS -- geographical knowledge acquisition and management system of MOGES

As a branch of AI applications, expert system uses knowledge as logical kernel. Geographical knowledge is the logical association of geographical data, such as, geographical planning, experience and phenomena. Therefore, geographical knowledge must be acquired from geographer. The level of acquisition and management of geographical knowledge is an important factor to show the level of GES.

Knowledge acquisition includes knowledge representation and knowledge refinement, and the former is the most important one.

Geographical knowledge representation may be defined as expressing geographical knowledge, such as planning, experience and phenomena, with abstract logical languages that can be understood by computer. This kind of expression can be inputted to computer and stored in knowledge base.

After analysing geographical research contents, we divide geographical knowledge into following three levels:
1. the basic level, which describes geographical independent factors is based on GCM;
2. the medium level, which classifies integrative geographical factors, is a group of classification rules;
3. the advanced level is a series of integrative geographical planning rules.

A kind of list language is designed to input geographical knowledge in MOGES, and there are several functions in the knowledge base management module or sub-system (see Fig.5).

2.3 GIE -- reason controlling module of MOGES

Inference engine controls the inference operation of the knowledge in the knowledge
base on the data in the database and gains the conclusion. This means that the inference is a strategy program composed of inference-control algorithms and knowledge-search algorithms.

By the use of the rules in the geographical knowledge base, the inference engine in the MCGES can match, calculate the data in the MCGIS (Global Data Base) to gain solution on the geographical problems with unknown model. This module can also provide reverse real-time explanation for the processes and results.

MCGES adopts production-strategy in reasoning.

In accordance with the three-level in knowledge, a complete inference procedure is composed of operations in three levels.

(1) Basic inference

Use the knowledge in the first level to match values of factors, and grade the factors;

(2) Medium inference

Based on the conclusion of the basic inference and the medium knowledge (rules) to classify the integrated geographical factor;

3. THE APPLICATION AND EVALUATION OF MCGES

MCGES is successfully used to solve many problems of soil and water conservation planning in Kouhe, a district in Liuhe valley, Inner Mongolia Autonomy Region.

Using following data and knowledge:

(1) topographical map of Kouhe, 1:100,000,
(2) geo-code Model map of Kouhe, 1:100,000,
(3) GOM rank table of Kouhe,
(4) erosion type classification rules,
(5) a new Erosion intensity model,
(6) soil and water conservation experience measures,

MCGES can gain following results:

(1) single factor output: value and map of slope, aspect, average slope, soil type, soil depth, gully density, vegetation coverage etc.

(2) integrated factor output: value and map of erosion intensity, suggests and maps of soil and water conservation measurement etc.