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 can not be defined by definite models and can not be solved by GIS. As the combination of geography and Artifical 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.

KEY WORDS: Geographical Expert System, Geographical Information System, Geographical Knowledge Base, Geographical Inference Engine.

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 trip to draw a serials of conclusion, and those conclusion will become experience for later geographer. Figure 1 shows the classical geographical methods.

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

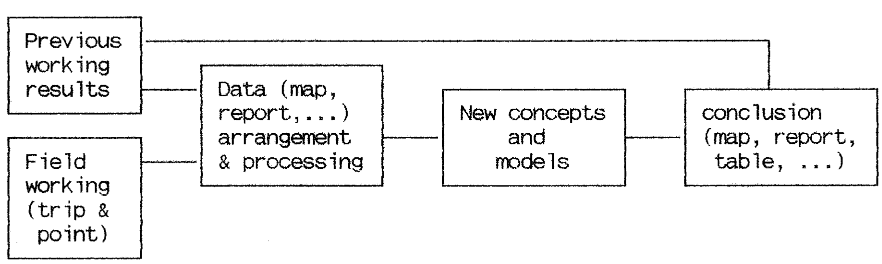

Fig. 1 Classical geographical methods

these knowledge to solve inexact and undefinite geographical problems.

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 quantative 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 geograhical models. GIS now is successfully used for geographical planning and resource management, such as landuse plan urban develepement. 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 problem.

GES is the combination of geography and Artifical Intelligence (AI) , and can be definated as

GES = GIS + artifical 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 reasonning with geographical knowledge, GES put geographical knowledge at the most important position. As Geographical data is the inference source, it is the reasonning object with geographical knowledge. There are three main problems in GES, which are concerned with geographical knowledge and data,that is,

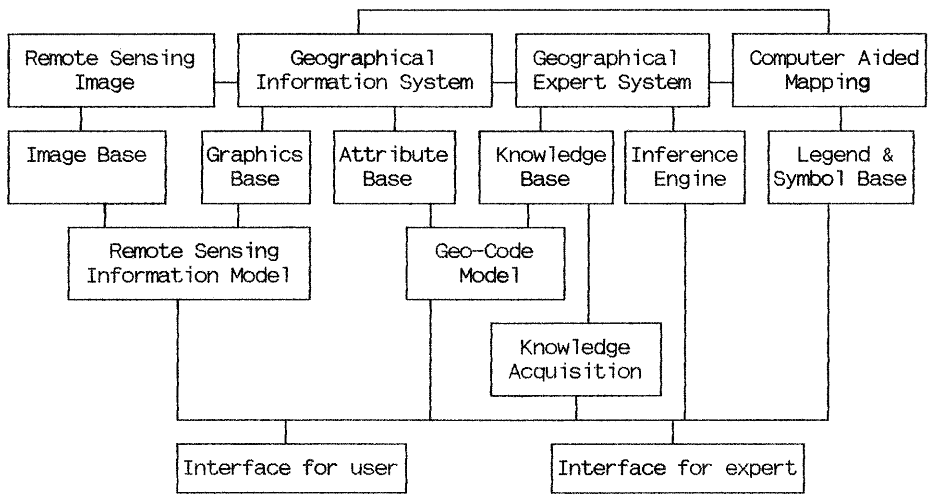

Fig. 2 Modern Geographical Methods

(1) How to gain and manage geographical data?

(2) How to acquire geographical knowledge from geographer, and formalize, represent and manage them ?

(3) How to control the inference with geographical knowledge on geographical data ?

We have designed a GES on Micro-Computer, which is called as Micro-Computer Geographical Expert System (MCGES) .There are three main module in MCGES, that is,

a. Micro-computer Geographical Information System (MCGIS), which is used to solve problem (1).
b. Geographical Knowledge Base System (GKB), which is designed to solve problem (2).
c. Geographical Inference Engine (GIE),which is designed to solve problem (3).

The structure of MCGES can be shown as Fig.3.

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 acquisite and manage data for MCGES. MCGIS not only can be used as an independent GIS,but also can be consistant 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.

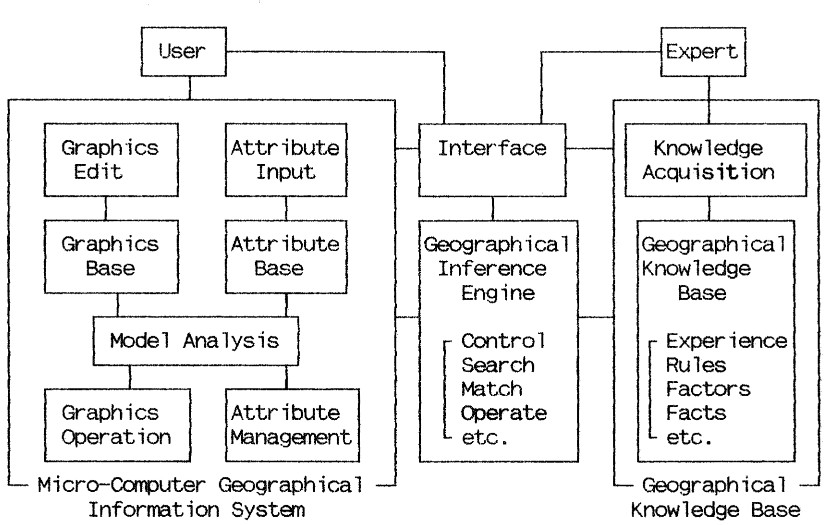

Fig. 3 The structure of MCGES

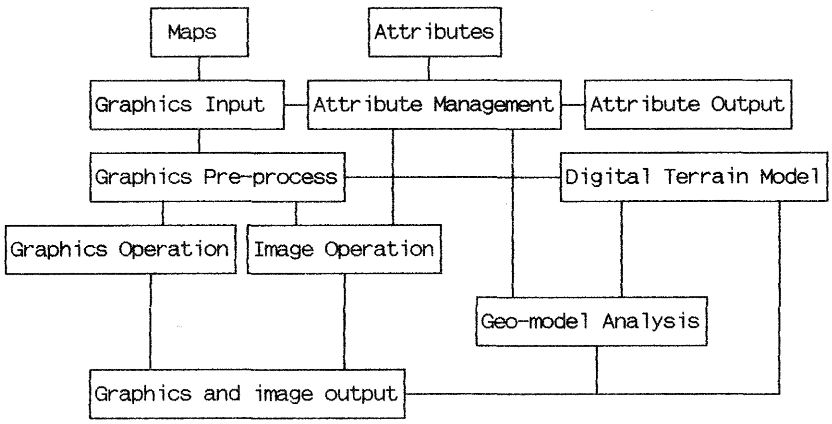

Fig. 4 The structure of MCGIS.

MCGIS 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 represent different attribute, with its value representing the attribute value.

Vector and raster (grid) are two basic graphics data formats used in MCGIS. 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.MCGIS defines two basic image operation, that is, image overlay and image extract, both of which are based on the GCM-expressed geographical attributes.

Image overlay can be expressed as

$$I1+I2+I3+...+In \rightarrow I$$

where

(1) I1, I2, ..., In are as independent geographical factor images (raster maps);

(2) I as an integrative geographical factor image,which is composed of I1, I2,...,In.

Image extract is the reverse calculation of image overlay,which can be expressed as

$$I \rightarrow I1+I2+I3+...+In$$

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

Generating Digital Terrain Model (DTM) is another important function of MCGIS. DTM can be expressed as

$$Ti=Fi(x,y)$$

where

(1) Ti as topographical factors, such as elevation,aspect,slope etc;
(2) Fi as the function of topographical factors to geographical coordinates (x,y).

MCGIS also uses a series of mathematic methods to solve geographical problems with known models.Those mathematic models includes multiply regression analyses model, tendency analyses model, cluster classification model and principal component analyses model and so on.

2.2 GKB -- geographical knowledge acquisition and management system of MCGES

As a branch of AI applications, expert system uses knowlege 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 analysising geographical research contents, we devide geographical knowledge into following three levels:

(1) the basic level,which describe and grade the 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 MCGES,and there are several functions in the knowledge base management module or sub-system (see Fig.5).

2.3 GIE -- reason controlling module of MCGES

Inference engine controls the inference operation of the knowledge in the knowledge

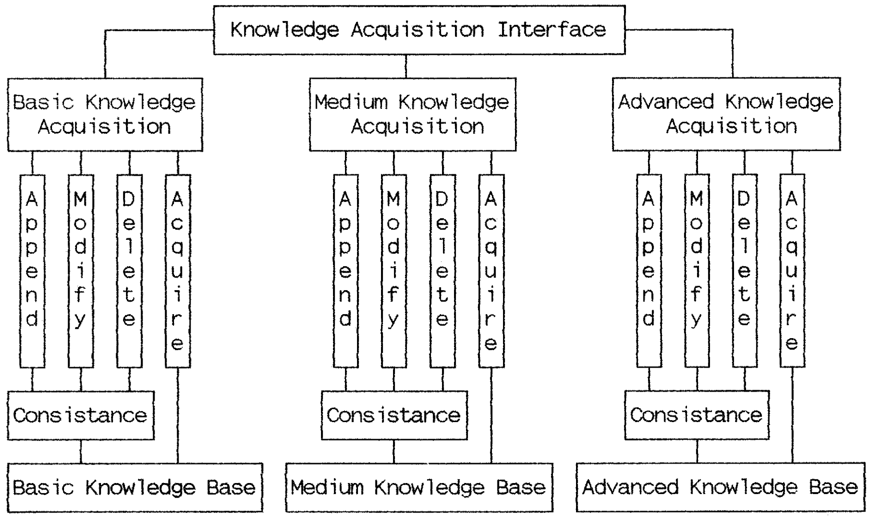

Fig. 5 The structure of GKBMS

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 reasonning.

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 Aotonomy Region.

Useing following data and knowledge:

(1) topographical map of Kouhe, 1:100,000,
(2) geo-code Model map of Kouhe, 1:100,000,
(3) GCM 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.