KNOWLEDGE ENGINEERING AND PHOTOGRAMMETRY TOMORROW

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Abstract

After giving a brief introduction to Knowledge Engineering, the situation and characteristics of Photogrammetry and Remote Sensing are examined, and the possibilities and strategies of applying Knowledge Engineering to Photogrammetry and Remote Sensing and developing various expert systems are discussed, upon which a conclusion may be drawn that it's an inevitable trend for Photogrammetry and Remote Sensing to progress and develop from Analytical to Digital and Intelligent.

1. INTRODUCTION

Knowledge Engineering(KE),which was raised for the first time by Prof. Feigenbaum in Stanford University in the international conference on Artificial Intelligence held in MIT in 1977, is an important field of Artificial Intelligence(AI). Although the emergence of AI can go back to the 1950's/1,2/,the most successful and active branch of it is KE or Expert System(ES), which has so far the most extensive application.It is the creation of KE and ES that made AI get rid of investigation into puzzle-guessing and games-playing in laboratories and come into practical use in engineering and other sciences/3,4,5/. So far KE has been applied to all the important sciences created by man,such as Cartography, Photogrammetry and Remote Sensing,Medicine, Agriculture, Geology, Meteorology,Hydrology,Transportation,Mathematics,Physics,Computer Science,Education and Military Science/2/. It has been predicted that the 21th century will surely be the golden times for AI.

KE(ES) is suitable for solving these problems which can not be accurately described by mathematical models (so called ill-structure problems). Through simulation of human thinking processes KE puts human knowledge into computers, which then solve problems and answer queries,reasoning and proving by using this knowledge/3/.

In fact, most of our tasks are not mathematical ones. It is impossible or very difficult to precisely describe them by definite mathematical models.People usually deal with this kind of tasks,using the knowledge and experience in their brains. The same is the situation in Surveying and Mapping.In addition to the tasks which can be described by mathematical models,there are also the tasks which can not be described by mathematical models, e.g. map compilation,map generalization,map use, image quality assesment, image interpretation and understanding,terrain analysis, blunder detection,aerial triangulation,stereo-observation(image matching) and so on.

Obviously,application of KE to Photogrammetry and Remote Sensing has broad perspective. The direction of development of

Photogrammetry and Remote Sensing is not only from Analytical to Digital,but also from Analytical to Digital and Intelligent.

In this paper the basic conceptions about KE and elementary components of ES are explained. Then after an examination of the state and characteristics of Photogrammetry and Remote Sensing, the possibilities and corresponding environments of developing expert systems in Photogrammetry and Remote Sensing are discussed. In the end we come to a conclusion that it is definite for Photogrammetry and Remote Sensing to progress and develop from Analytical to Digital and Intelligent.

2. BASIC CONCEPTIONS OF KE AND ES

KE is an art which puts human intelligence into computers and designs different kinds of expert systems which have the ability of processing intelligent information. Therefore,KE is defined as a general term for expert systems in different special fields/1/. Expert system is a computer software system which contains the knowledge and experience in one special field and , therefore,can totally or partly replace the human specialists or experts to work with the same or almost the same quality. According to the state (evidence or data) of a problem,expert system treats it cleverly like a human expert by using its understanding(knowledge) of the problem, rather than works as conventional computer programs which can only do the manipulation sequentially and regularly according to the fixed algorithms/4/. The following is concerned with the fundamental structure and key problems of an expert system.

2.1 the Structure of an Expert System/2/

A general expert system consists of five parts : knowledge base, data base, inference engine, interpretation module and knowledge acquisition module(Fig.1),among which knowledge base and inference engine are the two key components which concern the basic problems of KE,i.e. knowledge acquisition,knowledge representation, and use or processing of knowledge.

Knowledge base is the storage of knowledge in a special field. There are two kinds of knowledge : one is the fact i.e. common knowledge and knowledge in textbooks ; the other is the heuristic knowledge which is the expert's experience. Data base stores the initial evidence,intermediate results coming from reasoning, and final results(facts). Inference engine is a set of computer programs which control and co-ordinate the operation of whole system.According to the input data,the engine solves the present problems by reasoning based on the knowledge in knowledge base in some inference strategies. In ES the reasoning mechanism may be forward reasoning or backward reasoning,or the combination of them ,and it can also be distinguished into certain reasoning and uncertain reasoning. Uncertain reasoning is very important and remains to be an active investigation subject in ES.Interpretation module which consists of a set of computer programs is an interface between users and the system,the functions of which are to explain the reasoning results of the system, answer the users' queries in order to make users understand the reasoning processes, learn from the system and maintain the system. This module should have some ability of understanding natural language. Knowledge acquisition module is also called learning module,which is used to modify and extend the knowledge base. There are three kinds of knowledge acquisition methods :

- Automatic method: the system automatically summarizes and deduces experience and knowlegde from its own practice and adds them to the knowledge base.
- Semi-automatic method: the system finds out that there is a requirement of modifying and adding knowledge, and informs human experts of these messages,upon which human experts do the modification and addition.
- Manual method: the discovery of mistakes,the modification of the knowledge base and addition of new knowledge are completely done by human experts.

Through the cooperation between the experts in a special field and knowledge engineers and their common efforts an efficient and practical expert system can only be built up. The building and completion of an expert system are value-added processes. On developing an expert system,first a simple and primary system is set up,and then during the period of the debugging and using, the gradual improvement and completion are needed,so that the system can get better and grow to be a perfect expert system, e.g. the famous PROSPECTOR,which only had 3 models in its first year of development,the second year 5 models,and by the end of the fourth year was extended to 15 models, and has recently got new development/7/.

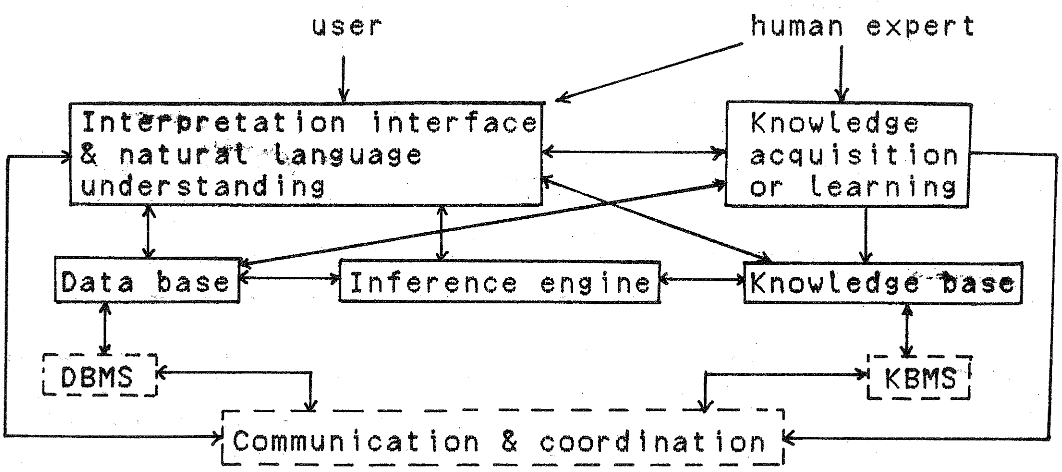

Fig.1 the structure of an expert system

Because the software of an expert system is usually very large,its design,maintenance and management are very significant/8,9,10/, which can be instructed by Software Engineering/10,11/.If the data base and knowledge base of an expert system are complicated, the data base management system(DBMS) and knowledge base management system(KBMS) can be used for their maintenance and management (Fig.1). If the KBMS is not available, the DBMS can be used as an alternative.

In a word, an expert system should be able to not only give the authoritative suggestions and advices of some special field, but also,when necessary,explain its own actions and answer the user's queries, in addition to the ability of knowledge acquisition.

2.2 The Tools for Developing Expert Systems/1,3/

There are two main tools: one is the language for the design of AI programs and the other is the special development tool.

There exist two main languages for AI programing: LISP and PROLOG. With LISP the knowledge can be represented as facts or procedures. LISP was first designed by Prof. John McCarthy in MIT in the late 1950's. Since then it has developed rapidly and found wide application,especially in USA. PROLOG means programing in logic, which began to be popular in Europe in the 1970's. In 1982 Japan declared that it took PROLOG as the nuclear language for its fifth generation of computers,which has drawn wide attention to PROLOG all over the world. PROLOG has a strong ability of logic reasoning ,a program of which consists of three parts : facts, rules and queries. Of course, other programing languages(e.g. BASIC and FORTRAN) can also be used to construct expert systems.

So far a large variety of versions of LISP and PROLOG has been developed,and some of them can operate on micro-computers also. Especially in certain versions of PROLOG, BASIC can be used as well.

Using programing languages to develop expert systems is a big job and usually needs 5 to 10 years for one person to do it/3/.However ,if existing expert systems are used as special tools,the building of expert systems will be considerably simplified,which only takes 2 to 5 years for one person to finish. In this case,what knowledge engineers should do is just to put the knowledge in some special field into a computer by using a special tool, which can be regarded as a general and normal KE tool, to form the knowledge base,and after debugging,an expert system is established/1,3/. The expert systems which can be used as special tools are EMYCIN,OPSS, M1,KAS,EXPERT and so on/1,3/.

3. THE STATE AND CHARACTERISTICS OF PHOTOGRAMMETRY

The variations in the methods and devices of data acquisition and data processing have caused great changes in Photogrammetry and Remote Sensing, the direct motive power of which should be dedicated to the development and application of computer science, and therefore we may say that Photogrammetry and Remote Sensing have stepped into a quite new age of computer-assisted automation or semi-automation.The theme of the symposium,sponsored by Co.3 of ISPRS and held in Finland in August of 1986,was from Analytical to Digital, which was considered as the state and the development direction of Photogrammetry and Remote Sensing/6/.

However,if we look wider and further at today's Photogrammetry and Remote Sensing,it is not difficult to find that they have the following characteristics :

- Some of the tasks in Photogrammetry and Remote Sensing are certain and can be precisely described by mathematical models. But many of them are indeed uncertain which can not be definitely described by mathematical models, and human experts usually treat this kind of tasks through their subjective judgements based on their own knowledge and experience, e.g. the choice of proper algorithms when doing image enhancement and segmentation.

- A variety of space sensors provides us with a lot of image information. Obviously we are far away from the full processing, developing and using of this information at present, and most of it is lost. Most of the existing geographical information systems(GIS) acquire their spatial information from maps,which takes a lot of manual labour. The storage cost is very high for an image data base and it is not application-oriented on the other hand. The workable way is to use the data coming from space sensors directly as an information source of GIS and integrate image processing system and GIS together. It is an important investigation field to make Photogrammetry and Remote Sensing to be integrated with GIS, to which a lot of attention has been paid and many achievements have been made as well/13,14,15,16/. Also,the integration here needs to deal with knowledge processing.
- In their practice photogrammetrists are usually just satisfied with the primary processing of original data, e.g. interpolation of DEM,contouring and production of orthophotos,rather than store and manage the data and the final results in an efficient way or use them as an information source of GIS directly. On the other hand, in the operation process of a system,the operator or system itself may extract some knowledge,experience and lessons, which are obviously used insufficiently.

The comprehensive processing and using of several kinds of complex data are in close connection with knowledge and experience,and now we are confronted with the tasks of application of KE in Photogrammetry and Remote Sensing. At present,the research in this aspect includes map generalization/3/,aerotriangulation and gross error detection/18,19/,image matching and computer vision/4/,image interpretation and understanding,and knowledge-based geographical information systems/20/.

4.APPLICATION OF KE TO PHOTOGRAMMETRY AND REMOTE SENSING

4.1 The Application Possibilities

- A knowledge-based DEM interpolation system

  First a knowledge base should be built up. Under a particular standard of accuracy,determine the relationships among terrain classifications,sampling intervals and interpolation algorithms (i.e. weight functions), and then put them into the computer (knowledge base) as knowledge.

  When sampling a topographic surface,the system first does the terrain analysis and gives the classification of the surface and the suggestions about sampling,according to which sampling is done. This process may be repeated several times until a satisfactory result is reached. When interpolating DEM,according to the variation of classifications the system automatically determines the corresponding algorithms by reasoning. The system should be able to explain its own reasoning process and, when meeting with difficulties, suggest modifying and adding knowledge.

Here there exist two problems : one is the reasoning mechanism and the other is the problem of the standard of accuracy, the method of terrain classification, the choice of the proper interpolation algorithms and the relations between them. Since the 1970's a lot of investigation into the latter has been made and many papers have been presented to the 14th and 15th congresses of ISPRS and the symposium in Finland. It seems that a set of feature factors may be used to classify terrain surfaces descriptively. There must be some correlations between classifications to some extent, therefore fuzzy classification and uncertain inference are inevitable.

- Computer vision/4/
  There are two possible ways: the image matching algorithm based on search strategies for AI and the matching algorithm based on the vision theory presented by Prof. Marr.

- Automatic and knowledge-based contouring
  In photogrammetric mapping,according to the mapping standards operators usually contour stereo-models by using their geomorphological knowledge and mapping knowledge and experience. If these knowledge and experience, formalized and stored in a computer, are used to guide contouring from DEM, the representation of terrain features will be improved much better.

- Knowledge-based automatic image interpretation system
  This system contains five parts : 1) knowledge-based image enhancement, edge detection, area segmentation and feature abstraction; 2) the knowledge base for automatic interpretation, classification and understanding; 3) the selection of inference mechanism; 4) the interface between the computer and users and natural language understanding; 5) knowledge acquisition. The first part is to process the original images and abstract information as data, which after integration with other information are used as the initial state of the data base to motivate the system.

- A knowledge-based GIS
  It is believed that the following intelligent processes will be included in the next generation of Earth science information systems/17/: data management(intelligent data base management and intelligent data ingest) and spatial pattern understanding (image understanding and intelligent feature detection, identification and classification).

  A knowledge-based geographic information system is characterized by the combination of data processing and knowledge processing and the ability of reasoning,natural language understanding and knowledge acquisition.

- A GIS-based advice and decision-making expert system
  An existing geographic information system is used as the data base,and the geographic knowledge,the algorithms and knowledge for decision-making and the procedures concerned are put into a computer to construct the knowledge base. On using the system, users query it and get their answers from it.

Future advice and decision-making expert systems will be ones based on several information systems coming from different professional fields,the development of which largely depends on that of local computer network techniques, distributed computer systems and the corresponding parallel algorithms.

- A knowledge-based expert system for automatic map generalization The rules and standards for map generalization and the human experts' experience about map generalization are formalized, and then put into the knowledge base.In order to store maps,a system of this kind should be supported by a relational data base or a GIS. Also it is necessary to deal with uncertain reasoning in this case.

- Blunder detection and aerotriangulation/18,19/

4.2 The Development Environments

In order to develop an expert system in Photogrammetry and Remote Sensing,the computer scientists and experts in Photogrammetry and Remote Sensing should cooperate closely and the programming languages or the special tools should be able to deal with both data and knowledge, for example in its programs PROLOG should be able to use FORTRAN or other advanced languages which are suitable for numerical calculations. If a ready-made special tool, the knowledge representation and reasoning mechanism of which should be fit for the particular field, or a ready-made natural language understanding system is employed,the period of time for building an expert system in this field will be greatly reduced. In this case 2 or 3 persons can establish an expert system in 2 or 3 years.

Concerning the environments of computers and system design, micro-computers can be used to develop small systems or make the workable research for large systems, and middle or mini-computres are suitable for the development of middle or large systems. For large software systems the so called software crisis also exists in Photogrammetry and Remote Sensing,which means that systems are so large that it is very difficult to control and manage them/11/. Software Engineering is needed for their design and development, because the software systems in KE are usually very large and complicated/8,11/.

5. CONCLUSION

It has been suggested that the measure of maturity of a civilization could be gauged by the amount of information and knowledge that it generates, but it lacks a most important consideration which is the effective use of this generated information and knowledge. Thus,the real measure is not only how much information and knowledge are being generated, but how well they are being organized, managed and consequently used/17/, which is very closely related with human knowledge and experience. In the Earth science,more and more people have come to realize the importance of knowledge processing, and pointed out that it is because of the lack of the relative knowledge that some problems remain to be difficult to treat. In the conference of Spatial Information Technologies for Remote Sensing Today and Tomorrow, many scholars have discussed the potential application of KE in Photogrammetry and Remote Sensing/13,17/. And in the conference of Deutsche Gesellschaft fuer Photogrammetrie und Fernerkundung (darmstadt,March,1985) and the conference of ASPRS(March,1986),the importance of AI and KE has been emphasized and their bright future of broad application has been shown. Therefore, instead of the not very correct consideration of Photogrammetry and Remote Sensing development from Analytical to Digital,we should say that they are developing from Analytical to Digital and Intelligent, which has become a definite and irreversible trend.

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