Are Cartographic Expert Systems Possible?

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ABSTRACT

One of the major current thrust areas for computer software development is artificial intelligence and particularly expert systems. Several attempts have been made to implement cartographic design expert systems. None of these, however, can either understand why particular decisions are reached, or explain the reasoning to the user. This self-knowledge is one of the principle properties of any expert system and so it is doubtful whether any of the systems reported to date deserve the epithet "expert". This omission is not the fault of the system developers, but is caused by a lack of any systematised and accepted methodology for cartographic assessment. The cartographic community is urged to address this problem expeditiously.

INTRODUCTION

There can be no doubt that artificial intelligence and its associated programming techniques have made a major and increasing contribution to the field of computer science in recent years. A brief perusal of the shelves of any academic bookshop stocking computer science textbooks will reveal any number of tomes, too many to list here, with titles varying on the theme of Artificial Intelligence and related areas. Equally there is an increasing literature on the application of these programming techniques, particularly expert systems, to many science subjects. In the area of Geography and Geology, a recent review by the authors and others revealed eighteen expert systems of which details are published, while Waterman (1986) identifies some sixteen systems and any number of other systems are in preparation. These could all be described as experimental, to a degree, but have proved most successful and are in day-to-day use in the oil and mineral extraction industries (e.g. PROSPECTOR Cambell et al. 1982, MUD Kahn and McDermott 1984) and in environmental management (FIRES Davis et al. 1986).

In view of this it is not suprising to note that more and more expert systems are being proposed which proport to be applications of artificial intelligence techniques to cartography. It is the aim of this paper to briefly review these applications and assess the extent to which they can truly be described as expert systems.
For various reasons it is not possible to preview the contributions to this conference and so comments made here should not necessarily be taken to relate to those contributions.

ELEMENTS OF EXPERT SYSTEMS

In spite of the large number of published textbooks and papers which discuss expert systems there is no generally agreed definition of what constitutes an expert sytem. Waterman (1986, p.25), however, lists four essential properties of an expert system:

(1) Expertise which means having a high level of skill, exhibiting expert performance and having adequate robustness;

(2) Symbolic reasoning, which involves symbolic knowledge representation and the ability to reformulate symbolic knowledge;

(3) Depth, which is the ability to handle difficult problem domains and use complex tasks;

(4) Self-knowledge, which is examining its own reasoning and explaining its operation.

The symbolic knowledge is held in what is known as a knowledge base, the compilation of which requires a body of explicitly stated facts. These may be in the form of published literature or may have to be extracted from human experts in the domain for which the expert system is intended. Thus, in preparing a geological expert system, a geologist is consulted; for a cartographic system, a cartographer.

These facts are manipulated by the inference engine to derive diagnoses, prognoses, interpretations and other end products. Many ready-made inference engines are available at this point and provide a convenient route for the novice to concentrate on knowledge organisation without being concerned with programming.

At any particular point in the analysis, the expert system should have a situation model of the state of the "product". This can be reported to the user at any time for his approval. Similarly, the system should be able at any time to justify its line of reasoning or conclusion (Self-knowledge). Finally, expert systems can generally handle levels of uncertainty in the information supplied to them by the user.

A feature of expert systems which has caused some interest, but cannot be considered diagnostic, is the ability to update the knowledge base, according to further input by the user or expert. This so-called learning capability is in fact more complex than it may seem, although a simple example is given by Naylor (1983).

From the user's viewpoint, expert systems can be described as systems that for any particular set of input parameters can identify one particular outcome as the correct or the most probable from a large number of possible outcomes. In PROSPECTOR, this is achieved by Baysian combination of probabilities, so that essentially for any situation the most probably correct outcome is defined (Waterman 1986 p 55-57). This also enables the handling of uncertainty in user input.

CARTOGRAPHIC EXPERT SYSTEMS?

A number of cartographic expert systems have been described in the literature. These can be divided into systems for map and spatial data interpretation, systems to advise on how to produce maps; and systems for fully automated map production. These classes can be exemplified by the following systems: MAPSEE (Havens and Mackworth 1983), WERP (Taniguchi et al. 1984) and KBGIS (Smith et al 1984) are all involved to some extent with understanding maps and spatial data. The unnamed system presented by Muller et al (1986) supplies advice on how to construct maps, relating data types, among other variables, to map type, projection, etc; the consultation is purely verbal. Finally, the systems presented by Freeman and others (Freeman and Ahn 1984; Nicherson and Freeman 1986) and Pfefferkorn et al.(1985) all carry out some element of the map design process. The authors of this paper are principally interested in the design phase of cartography and so this paper is concerned primarily with the last of these groups; the reason for their apparent success is that they deal with just one element of map design, the objective of which is well-constrained and relatively easy to mathematically define. We are led to believe that such systems can be used as building blocks for more complex and "realistic" expert systems. This is not the case; the complete cartographic expert system will not be a set of independent design elements stacked together, but a system that considers all aspects of design at each stage of map compilation.

As noted above, one of the essential features of expert systems in other fields of application is that they are capable of taking a problem with a large number of possible outcomes and isolating the optimum solution. Similarly, the ability to justify the outcome is a pre-requisite of an expert system. Without wishing to detract from the quality of the software reported, neither of these requirements are met by the current map design expert systems. They all create one acceptable solution according to the production rules they are equipped with, without considering any other possible solutions. Name placement, the main area of cartographic production in which the authors are aware of expert system development (Freeman ansd Ahn 1984; Pfefferkorn et al. 1985) is an area where rules and evaluators (not overlapping previously positioned map names and features) can be clearly defined. There are some further areas of cartographic production where expert systems are under development, including parts of the generalisation problem (Nickerson and Freeman 1986). However, it is debatable whether any of these deserve the epithet expert system, principally because they have no self-knowledge, being wholly unable to explain their reasoning in establishing a particular outcome, or why one outcome and not another was achieved.

The task of knowledge engineering has been made still more difficult given that "no generally accepted concept of the process and functioning of cartographic communication exists" (Freitag 1980, p 18), an opinion shared by many other authors, if stated by them in other ways (eg Robinson 1975; Cuff and Matteson 1982). Self-knowledge for a cartographic expert system can only be achieved, however, when just such a concept exists and is accepted within the cartographic community. It is possible that the seminal work of Bertin (1984) may provide a basis for establishing such a concept, but there is much to be done to achieve it. Without clearly stated methods of assessment, a cartographic expert system can neither choose between alternative candidate designs, even in relatively simple areas of cartography such as name placement, nor act at all in more complex areas such as the assignment of symbols.

CONCLUSION

The authors are concerned that the development of cartographic expert systems will continue, irrespective of the lack of any widely accepted and clearly stated method of map assessment, and that if cartographers do not get on and develop the required methods, these expert systens will be produced by computer scientists not principally concerned with cartography.

In short, therefore, the authors firmly believe that cartographic expert systems are possible and, indeed, computer systems with some characteristics of expert systems are in existence. Self-knowledge, one of the major properties of an expert system is, however, at present entirely lacking and cartographers should be concerned to rectify this omission.

ACKNOWLEDGEMENT

The opinions expressed here were formulated during collaborative research with G Wilkinson, G Robinson and M Jackson, to whom we extend our appreciation.

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