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AN ASSESSMENT OF EXPERT SYSTEMS APPLIED TO PROBLEMS IN GEOGRAPHIC INFORMATION SYSTEMS*

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Abstract. A previous paper provided an introduction to expert systems. In this paper we assess expert system efforts in areas of particular importance to the development of Integrated Geographic Information Systems. We identify three general problem domains in which current expert system development efforts are concentrating. They are: (1) automated map design and generalization, (2) terrain/feature extraction, (3) geographic database management/user interface. Within each problem domain we critically assess the characteristics of reported systems. In the domain of map design we assess AUTONAP, ACES, and MAP-AID. A number of terrain/feature extraction systems are discussed. Among them are ACRONYM, FES, and CERBERUS. Here we include systems for terrain extraction as well as landuse classification. Finally, we discuss two KBGIS systems, LOBSTER, SRAS, and ORBI in the context of geographic database/user interface problems. Very few if any of the reported efforts have reached a level practical for everyday use. It is instructive to review these current efforts since they represent the nature of future applied systems. Following the survey of current efforts we identify future research and application themes. In particular, we consider an application of expert system technology to the management of land records information. We come to the conclusion that expert system for geographic information system applications can presently be built. However, we feel it not yet advisable to begin large-scale, integrated projects. The primary reasons being the lack of basic tools for building expert systems as well as the poor state of formalization of geographical concepts.

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Introduction

A previous paper briefly discussed the nature of expert systems. In this paper we critically survey several expert system efforts in areas of particular importance to the development of Integrated Geographic Information Systems. Following the survey of current efforts we identify future research and application themes. In particular, we consider an application of expert system technology to the management of land records information. We come to the conclusion that expert system for geographic information system applications can presently be built. However, we feel it not yet advisable to start any large-scale, integrated projects. The primary reasons being the lack of basic tools for building expert systems as well as the poor state of formalization of geographical concepts.

Current Expert Systems Applied to Integrated Geographic Information System Problems

Development of expert system for application to problems confronting integrated geographic information systems has been reported by a number of investigators recently. First let us consider some of the major problem domains of integrated geographic information systems particularly applicable to expert systems. Our problem domains are similar to those reported in Robinson and Jackson (28), but are more general than their cartographic problem domains. The problem domains are : (1) automated map design and generalization, (2) terrain/feature extraction, (3) geographic database management/user interface.

Table 1 reports reported activity in development of knowledge-based systems according to problem domain. As indicated by Table 1, most activity has been occurring in (1) and (2). However, very few if any of the reported efforts have reached a level practical for everyday use. It is neverthless instructive to review these current efforts since they are prologue to future system developments.

Map Design

Robinson and Jackson (28) outline the MAP-AID project being undertaken in the United Kingdom. They envision their expert system being divided into four components: (1) the 'core' containing the map design rule-base and other information held as rules in the knowledge-base; (2) the user module through which the user controls the system and interacts with the knowledge-base; (3) a set of data-system modules; and (4) a set of graphics package modules. Prolog will be used as the primary language for the development of this ambitious expert system.

AUTONAP (1, 9) is perhaps the most successful name placement expert system developed to date. This system emulates an expert cartographer in the task of placing feature names on a geographic map. It utilizes heuristic knowledge about map placement based on established procedures and conventions. The knowledge base consists of a small set of explicit rules (approx. 30) largely organized as subroutines in a large (approx. 12,000 lines) RATFOR program on a Prime 750.

The general approach is that area features are annotated first, then point features, and finally line features. In this manner the system progresses from the most constrained annotation task to the least constrained feature annotation task. There is some backtracking reported as part of the system. For example, in point feature annotation, if it becomes impossible to place a name, the system backtracks, removing names already placed, placing them in different positions. Although the it is sometimes described as a 'rule-based' system, AUTONAP is not a true rule-based system because the rules are implicit in the RATFOR program rather than existing an independent rule-base.

Once the placement of area feature names has been accomplished, a free-space list and possible-positions list are developed and used in subsequent name placement tasks. These two lists essentially form a graph of permissible name placements and locations. In point feature name placement tasks a heuristic graph-searching algorithm similar to the A* algorithm (21) is used to search the state space. Finally, line feature names are placed according to a set of rules and constrained by the location of point and area feature names.

This expert system has produced some impressive results (9) accomplished in a fully automated manner. Although, it is not written in one of the typical artificial intelligence languages such as Lisp or Prolog, it is claimed by its developers that additions can easily be made to the knowledge base by incorporating additional FORTRAN subroutines.

Pfefferkorn et al (24) report a cartographic expert system, ACES, for labeling maps that is similar in objective and approach to AUTONAP. A decision tree is used to control the search behavior of ACES during its search of the state space. However, their processing sequence and many of their measures of placement and priority are quite similar to those used by AUTONAP.

Terrain/Feature Extraction

Palmer (22) showed how logic programming (Prolog) can be used as the basis of an expert system for analysis of terrain features. Using a triangular tesselation he represented nodes with their elevation, segments and triangles as first-order predicates. Then using Prolog to conduct symbolic analyses he demonstrated how valleys, streams, and ridges could be detected using the procedural knowledge encoded in a knowledge base and using Prolog control mechanisms.

ACRONYM is an image understanding expert system that has been discussed in more detail by Brooks (4) and Lambird, Lavine, and Kanal (15). It does symbolic reasoning on two-dimensional images using three-dimensional models. Of considerable interest is that this system incorporates three expert systems. Each of the three expert systems have their own knowledge representation and type of reasoning, and they co-operate to interpret images. The expert systems are: (1) a prediction system using three-dimensional models to predict geometrically invariant features to look for in an image; (2) a description system using an image to obtain descriptions of possible image features; and (3) an interpretation system that uses the descriptions from the expert system (2) to find constraints and check for consistency in the results. Graph matching is used to perform reasoning. The three systems are iterated (prediction to description to interpretation) in order to get increasingly more detailed interpretations of the image. Thus, ACRONYM makes extensive use of AND/OR graphs. ACRONYM has been tested on a limited amount of imagery for a small set of objects. Thus, Lambird et al (15) suggest that the control mechanisms in ACRONYM are unlikely to be able to handle interpretation of complex images containing a large set of complex objects.

FES is a Forestry Expert System reported by Goldberg et al (12) used expressly to analyze multi-temporal Landsat data for classification of landcover and landcover change of interest to foresters. Using a multi-temporal Landsat image database, production rules are applied in two phases. First production rules are used that involve change detection inference coupled with a reliability measure. These first-phase rules decide whether the changes in classification from one time period to another are real or represent statistical artifacts. The second phase generates a set of decision rules regarding the current state of the image. For example, a new decision in the second phase could be arrived at in the following manner: 'Given the the previous decision was softwood, and a statistically significant change has occurred, specifically softwood to clear-cut, it can be concluded that the area represented has undergone logging.' The control structure of FES has been described as a 'feedforward' system where once a decision has been reached in the second phase the system starts another iteration. There is apparently no backtracking. However, there is a provision for the addition of production rules by an expert should 'anomlous' situations occur. FES was tested using imagery covering 100 sq. km. in central Newfoundland, Canada. The imagery spanned a period of six years. Results led Goldberg et al (1983) to conclude that system could track both highly discernable and very subtle forest changes.

CERBERUS is an expert system still under development at NASA for the purpose of performing unsupervised classification of Landsat mulitspectral data (6). It is based on a production system of IF-THEN rules represented by a rule network. The control structure uses forward-chaining strategy with no real backtracking. One of the major deficiencies is the inability of the expert system to access a database of multispectral measurements. Currently the user must supply the data. There is an attempt to cope with uncertainty in this system using confidence factors as first used in MYCIN. It is unclear how significantly this system differs from FES, at least in the unsupervised classification aspects. In fact, both FES and CERBERUS use similar approaches in structuring the knowledgebase. Also, they have both attempted to had to develop methods of dealing with uncertainty at an early stage of development. This suggests that landcover classification is a decision process fraught with uncertainty in data and inference.

VISIONS and MAPS are image-based systems under development. MAPS is being developed at Carnegie-Mellon University as prototype interactive aid for photointerpretation. Similarly, VISIONS is under development at the University of Massachusetts as an experimental environment for image interpretation system development. Both these systems rely heavily on the

Lisp programming language. An hierarchical knowledge base is used in VISIONS. Both are currently working on problems related to integration of multiple data sets.

Geographic Data Base Management/User Interface

There are a number of on-going efforts reported in this very complex problem domain. However, there has not been reported in the literature a working Knowledge Based Geographic Information System (KBGIS). The closest that one gets to a true KBGIS is the ORBI system (23).

ORBI is an example of an expert system implemented in Prolog. It intends to keep track of environmental resources for the country of Portugal. There are aspects of both a classification system for environmental data and a decision-support system for resource planning. ORBI provides graphic input and output of maps via a digitizing tablet and plotter, a natural language parser for Portuguese that supports pronouns, ellipses, and other transformations, menu handler for fixed-format input, an explanation facility that keeps track of the steps in a deduction and shows them on request, and help facilities that explain what is in the database, the kinds of deductions that are possible, and the kinds of vocabulary and syntax that may be used.

It is a remarkable system for another reason. ORBI runs on a microcomputer with only 64K bytes of RAM storage. Thus, requiring overlays for the language processor, deduction component, and explanation facility. With the possible exception of LOBSTER, this is perhaps the most sophisticated geographic database expert system. However, it application to very large spatial data bases has not been demonstrated.

LOBSTER (7), like ORBI, is based on the logic-programming paradigm. It is a new implementation of a task previously solved using a traditional programming approach, namely a query language for a geographic database (8). It serves as an intelligent user interface to a spatial database managment system using the network data model rather than the more common relational model. LOBSTER helps answer typical queries in a GIS including production of simple maps. It is felt that the flexibility in building the interface using a Prolog-like language was significant.

SRAS (25, 27) is a spatial relations acquisition station. It is concerned with acquiring representations of natural language concepts to be used in subsequent queries of a geographic database. This is an mixed-initiative, question-and-answer system that chooses questions based on anticipated user response and its effect on the representation of the NL concept. It is one of the few reported systems utilizing fuzzy set theory and analogical reasoning.

Smith and Pazner (30) reported on a prototype KBGIS that makes extensive use of a number of vintage methods drawn from the field of artificial intelligence. The objective of this system appears to have been to illustrate the use of techniques of artificial intelligence for search and simple learning on a spatial database. Properties of grid cells, such as land use, were organized in a hierarchical manner using AND/OR trees. One of the interesting aspects of this system is the integration of quad-tree with discrimination nets. Some simple learning has been incorporated into this geographic information system. They also seem to make use of the AQ11 inductive learning procedure (17). Currently, this KBGIS has been undergoing complete revision (30).

Glick et al (11) provide a more comprehensive design for a KBGIS using what they call hybrid knowledge representation. In contrast to Smith and Pazner (30) who chose data structures that fit easily into the scheme of discrimination nets, they (11) have chosen to use a variety of representation methods that depend upon the nature of the entity to be represented. In this KBGIS the geographic knowledge base is a bi-level spatial data structure consisting of a relational database and an arc-node structured positional database. The relational database contains knowledge that describes geographical entities such as polygons, lines, countries, their attribute/values, and relationships with other entities. The use of a frame-based semantic net to represent the 'meaning' of geographical objects and their interrelationships provides the capability to incorporate new entities, attributes, and relationships into the KBGIS. Importantly this KBGIS includes semantic knowledge and a semantic analyzer that bridges the gap between the user's understanding of the world and that of the computer.

Future Prospects

Users of interact with expert systems in three fundamental modes. The most common user-mode is 'user as client' where the expert system obtains answers to problems and informs user of its decision. Second most common is 'user-as-tutor' where the user is a domain specialist acting to increase the system's knowledge. Least common and understood is the mode of 'user-as-pupil' where the user actually harvests the knowledge base for human use. In other words, if a system codifies knowledge, then adds knowledge, we can subsequently learn what, how, and why new knowledge has been added when the knowledge base is harvested. As expert systems develop the 'user-as-tutor' and 'user-as-pupil' modes will become increasing prevalent.

There are two approaches one may take in mapping out prospects of future expert system developments in the area of integrated geographic information system. First, we may consider the past as prologue to the future. Second, using what has been learned about developing commercial expert systems, we may identify some areas that are amenable to the application of expert system technology. Our view of these prospects is moderated by constraints of current technology and resources required to implement a working expert system.

Past as Prologue.

Some of the key ingredients of building a successful expert system, are, according to (13), (1) attack problems amenable to the techniques of artificial intelligence, and (2) consider only important, difficult, high-value problems, (3) choose a problem that experts can solve in three minutes to three hours, (4) choose a problem the solution of which requires primarily symbolic reasoning, (5) rule out problems in which experts disagree about solution correctness, and (6) select an initial class of problems for solving that requires only a subset of a given knowledge area. Many of the current systems were and are being developed in a research environment. Therefore, they are not all characterized by the full set of above ingredients. In fact, there seems to many problems in the area of GIS application where experts do not agree on a single solution.

The map design problem is likely to continue to be a focus of expert system application efforts. It is an important, difficult, high-value problem. For example, Ahn (1) claims that the name placement process alone consumes more than 40 percent of the time it takes to prepare a maps and requires an experienced cartographer. Further refinement of the name placement process will continue. One of the areas of near-term research will probably consider how rules vary according to (1) purpose of map, (2) regulations involved, (3) scale of map, and (4) cultural expectations. Name placement is only one aspect of map design, but contains many of the characteristics of a problem domain amenable to expert system application. As progress is made in the area of name placement, other areas of map design are likely to come under increasing scrutiny such as choosing symbols, line widths, projections, etc. Of some significance to the further development of expert map design systems is the fact that this is not an area where experts agree about a correct solution.

Terrain/feature extraction is likely to continue as a very active area of expert system development. However, due to the military uses of such systems their support and development is likely to continue under the auspices of the Department of Defense. Some of the non-defense related work such as FES will continue to focus on the problems of landuse/landcover classification and monitoring. As these efforts continue the importance of managing uncertainty in the system will increase. Already, there are indications that its importance is being felt. For example, FES (12) included a reliability measure and Shine (29) has reviewed the utility of Bayesian, Fuzzy, and Belief logics in feature extraction systems. One of the future concerns in this field will be in the resolution of contradictory information resulting from the use of several types of sensors.

Database management/user interface is less well-defined as a problem area than either map design or terrain/feature extraction. User interfaces making use of user-stereotypes is likely to evolve out of work of Robinson et al (25). While the LOBSTER (7) and ORBI (23) have demonstrated the ability of logic programming to serve as an intelligent user interface. Use of logic programming in this capacity is likely to increase once its capabilities are illustrated in a practical context to a broad audience of users. Much of future work in spatial data error analysis, data capture and storage, and data transfer will be conducted within the context database management/user interface. Development of spatially distributed databases containing data from a wide-variety of sources will most likely encourage development of expert systems that can (1) navigate through the system in response to a query, (2) combine contents of different databases, and (3) determine a the reliability of the information provided the user. It may even use a user-stereotype to help reduce the computational burden of the search.

Formalizing Knowledge

What is most notable about the efforts currently underway or proposed is that there is a less than rigorous concern for the process of knowledge acquisition. Future development of expert systems will bring about a need for formalizing a great deal of knowledge previously left, at best, partially formalized. For example, let us consider the name placement problem. Freeman and Ahn (9) noted that 'Although much has been published about name placement (14) there are also many aspects [of the name placement problem] that are embedded in the unwritten lore of the cartographer's trade, often passed only by word of mouth (or display of examples) from one to another.' Likewise, in the context of building an expert system for map design, Robinson and Jackson (28) have noted that rule identification (ie knowledge acquisition) raises fundamental questions in cartography and constantly tempts one to be sidetracked. For example, a simple sounding rule as expressed by a design cartographer (of the human sort) such as 'don't use too many strong colours on complicated data', leads one into questions of perception of colour, measurement of colour, spatial interaction of colour, etc.

Systems such as ACRONYM, FES, and LOBSTER have facilities for adding rules to the rulebase, but do not have formal knowledge acquisition facilities. The closest one comes to a system focusing on knowledge acquisition is in Robinson's (25) SRAS. In SRAS the objective is not to extract rules from the expert but to acquire a 'fuzzy' representation of a spatial relation. Therefore, there is a lack of true knowledge acquisition capability. Both the KBGIS's discussed earlier claimed in their design to have 'learning' capability. However, none appear to have incorporated a general method for acquiring expert knowledge although Glick et al's (11) KBGIS seems to be the most capable in the area of knowledge acquisition. It is anticipated that knowledge acquisition will soon assume a prominent role in these systems. Once this occurs we will encounter the next level of the problem- conflicting rules. It is rather significant that no reports of actual implementation have been reported.

One of the advantages to formalizing knowledge in a knowledge-base system is that conflicting rules can be identified. However, this remains a very difficult process. Their resolution may bring us new insights into our decisionmaking process's strengths and weaknesses. And there is every possibility that different expert systems can arrive at somewhat different conclusions, like human experts. Much recent research in the field of artificial intelligence and expert systems concerns one of the byproducts of knowledge formalization - the formalization of uncertainty (16). As knowledge of expert systems applied to databases grows it is likely that the issue of uncertainty will grow in importance. As often occurs in geographic systems, a fact is known only to an approximate degree. The importance of approximate reasoning and fuzzy representation of facts has yet to be explored in the field of geographical expert systems. Neverthless, if the experience of other fields can serve as lessons, we will also become very concerned with the issue of uncertain knowledge in geographic information system technology.

Our discussion of current efforts as prologue to the future has led us to identify a number of research areas where results are necessary before expert systems in the area of GIS can be routinely built. The areas are -

- Improved facilities for editing, viewing, and organizing knowledge in an expert system and extension of expert system shells to work with very large data collections and also larger collections of rules than presently feasible.

- It must become possible to incorporate simple procedural operations, including numerical computations, into an existing inference engine. Such procedural operations may be used, among other things, to produce graphical output or do computations.

- Several of the concept areas in geography must be explored and become more formalized as presently available. Such areas contain most of cartographical design rules, terrain analysis, and geomorphological feature extraction (including the proper way to drawing contour lines), extraction of natural and man-made features (here again a suitable theory for classification would be very helpful), etc. In particular the formalization of the different types of uncertain geographic knowledge (26).

Finally, we feel that actually attempting to build a prototype expert system with a very limited area of application could be justified just on the amount of insight gained in the process of building it. The languages used to build expert systems typically help to formalize knowledge - a benefit independent of the possibility of automatic deduction.

Expert Systems and Land Records

What is perhaps most notable in this brief survey of expert system activities relevant to integrated geographic information systems is the lack of focus on problem domains with bearing on nonimage-based, land records. There are several areas ripe for future expert systems development in the field of Land Information Systems. However, in many cases substantial database problems must be solved first. LOBSTER (7) may be able to serve in the future as an intelligent interface to a wide variety of land information. Given its use of Prolog for accessing a network (CODASYL-type) database, the elaboration of its query facilities into a true expert system for title searches, property assessment, resource evaluation, and other functions will be relatively straightforward. Theoretically, this is also true of the ORBI system, but it might not easily adapt to the very much larger database to be exploited.

Let us take an example of a land records problem domain that is a 'high-value' problem, can be decomposed into subproblems amenable to development of an expert system. Title searches are typically tedious and inefficient, increasing the possibility of errors being made. Such a search requires many hours of a lawyer's time, hence is time-consuming and costly. Title records are kept in many offices. The offices, hence databases, are often spatially distributed. This is a high-value problem domain, but it is much too large for a single expert system development effort to cope with.

To identify the subproblems leading to 'specialist' expert system let us consider what should be included in a title search :

(1) determination of the accuracy of the legal description and its location on the ground;

(2) examination of the legal descriptions of adjacent parcels for boundary conflicts, hence extraction of parcel topology from natural language descriptions;.

(3) search for pertinent deeds, mortgages, and other documents such as protective covenants and equitable servitudes affecting the specific parcel;

(4) listing of liens;

(5) ascertainment of applicable building, occupancy, safety, fire, sanitation, and zoning codes, and whether or not there are any violations thereof; and

(6) inspection of the parcel for evidence of any unrecorded interests or encroachments.

Components (1) and (2) above involve expert systems that have the ability to translate natural language legal descriptions into representations that can subsequently be used to infer descriptions of spatial accuracy, location, and boundary conflicts. The land records database in most counties of the United States is not in a form allowing efficient interrogation by an expert system. Access and navigation through both Judicial and Geographic data systems would be required (5). A significant technological development would be the development to acheive the capability of generating a translation of a legal description in order to formulate queries to pass to the geographic database component to identify conflicts in boundaries, or inaccuracies in description.

A system to search for pertinent deeds, mortgages, and other documents such as protective covenants and equitable servitudes affecting the specific parcel would need to know how to navigate through a 'Judicial' data system and a Geographic data system (5). Navigation would be only one of the needs, the other would be to properly identify pertinent deeds, mortgages, and other documents such as protective covenants and equitable servitudes affecting the specific parcel. One the abilities needed in this system would be an ability to recognize and explain associations between documents and parcels that are not always obvious.

To obtain a listing of liens on a parcel an expert system would need to have access to both a Judicial data system and a Fiscal data system. As in the above task, there would need be an ability to recognize nonobvious associations and explain how those associations were arrived at. Simply saying 'the computer says there is a lien against your property' is not acceptable.

Ascertainment of applicable building, occupancy, safety, fire, sanitation, and zoning codes, and whether or not there are any violations thereof is perhaps the most difficult of any of the subsystems that might be contemplated. A large number of spatially distributed databases must be accessed and navigated by the expert system. Decisions must be made regarding the applicability of codes from a variety of enforcement agencies and those decisions unambiguously tagged to a particular parcel. A very significant problem here will the solution of differing semantics. That is to say an expert system using information from the fire department will have to be capable of translating that organization's language into terms meaningful when viewing the zoning codes. That is to say the problem of semantic integrity among distributed databases will be of a particular problem in this task.

The above brief discussion of tasks in a land title search expert system assumes that the various data systems are in digital form, accessible, and navigable by an expert system. Such a fortuitous situation is fairly rare in the United States. Thus, it is most likely that a working expert systems of this sort will be developed at locations most advanced in developing a multipurpose land data system such as that suggested by the North American Institute for Modernization of Land Data Systems (3). This highlights the dependence of expert systems upon advanced computing infrastructure.

Concluding Comments

In conclusion there are several comments on the future prospects of expert systems in relation to integrated geographic information systems. Generally speaking, to build integrated expert systems for geographic information systems today is not an easy task. Also, given the current computing infrastructure, expert systems are likely over the near-term to remain largely research/experimental systems which are tentative by nature. Developments are most likely to follow those already emerging. Possible exceptions relate to any well-defined, primarily diagnostic problem domain not dependent upon large land record databases.

Among the many problems of integrating expert systems with geographic information systems technology, we must contend with the limited capabilities of present day expert system shells, especially using their support to organize domain knowledge expressed in many somewhat related rules and the present problems the inferencing components have with large databases. Furthermore, we are confronted with the lack of formalism typical in geography and related scientific fields. It seems most appropriate to improve this situation by building smaller prototype expert systems with very limited scope to clarify concepts and formalize them.

It seems possible to build integrated systems today, but we would not recommend such efforts yet. We caution that the magnitude of the task coupled with the absence of good tools will almost certainly lead to solutions that are poorly organized and do not expose the general rules and theories that will be helpful in the future (This is somewhat like the enormous FORTRAN or COBOL programs in the early days of computing which did not help to further our insight into the principles of computer science). Smaller prototypes that are based on a proper language of artificial intelligence such as Lisp or Prolog, and with formal semantics, will not only bring practical results but more importantly will formally explore some of geography's less formalized areas. Lessons learned in building these smaller systems will in turn be transportable to later more advanced systems. Therefore, we come to the conclusion that expert system for geographic information system applications can presently be built. However, we feel it not yet advisable to start any large-scale, integrated projects. The primary reasons being the lack of basic tools for building expert systems as well as the poor state of formalization of geographical concepts.

The growth of expert systems is subject to further development and acceptance of a supportive technological infrastructure, among which lies integrated geographic databases. Integration of relevant databases will require subsystems just to manage transformations, insure semantic integrity, and provide aid in navigating among the network of databases. Thus, one of the first chores that an expert system is libel to be developed for may be simply to know where what is and what it means in terms of other database terms.

Finally, in the long-term the most important element influencing the future of expert systems will be their acceptance, or rejection, by the professional community. This will depend upon how 'friendly' and useful expert systems are designed. Often professionals are afraid of expert systems replacing them. Historically, they have not replaced trained professionals, rather they have proven to be extremely powerful professional tools.

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Table 1. Some Currently Reported Expert Systems in Relation to Geographic Information System Problem Domains.

Problem Domain	Expert System
Map Design	
General	MAP-AID
Name Placement	AUTONAP, ACES
Terrain/Feature Extraction	Palmer (22), ACRONYM, FES CERBERUS, VISIONS, MAPS
Geographic Database Management/User Interface	LOBSTER, SRAS, KBGIS-I, KBGIS-II, ORBI

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