# EXPERT SYSTEM INTERFACE

# TO A GEOGRAPHIC INFORMATION SYSTEM

Bruce W. Morse
Senior Scientist
Autometric, Inc.
343 W. Drake Rd. #105
Ft. Collins, Colorado 80526
303-226-3282

## ABSTRACT

Decisions concerning management of national forests require advice from experts of many different disciplines. Much of the information required from these forest management experts are spatial in nature; i.e. tree stand size, proximity to roads, slope, underlying soil type, etc. The analysis of this spatial data is facilitated using geographic information system (GIS). Yet the transfer of the expert's knowledge concerning spatial relationships related to forest management may require skilled use of a GIS, a skill which few experts in forestry possess. The system developed requires the forestry expert to provide the "if-then" relationship between the characteristics of the tree stand and the management recommendation. For instance, if an Aspen stand is 100 acres, on good soil, and within a quarter of a mile from a road, then that stand should be managed for timber, or whatever the expert decides. The "if-then" rules, which are easily entered into the expert system by the forestry expert, automatically access the GIS and its spatial database to provide forest management recommendations.

## INTRODUCTION

Natural resource management has been radically altered through the introduction and use of automatedinformation systems. Resource managers are currently assisted by database management systems (DBMS) which handle their textual and numeric data and geographic information system (GIS) which handle their spatial data. More recentlyexpert systems are begining to be used to assist resource managers in handling their knowledge. Nevertheless the lack of true integration of these technologies can stifled the advantages these automated

systems offer, such as speed and completeness in making management decisions. The lack of system integration has been recognized in handling text and numeric and spatial data resulting in the abilities of GIS to easily store and manipulate text and numeric data which has been associated with spatial data.

Analysis of text/numeric/spatial data is routinely accomplished through the interaction of experts familiar with the resource management decision at hand. The introduction and use of expert system technologies not only automates the storage and manipulate of knowledge, or expertize, it also affords the opportunity to intergrate the analysis of text/numeric/spatial data using the expertize embeded in an expert system.

This paper describes a system which interfaces an expert system with a GIS. The work performed for this effort was accomplished under a cooperative agreement between the U.S. Forest Service, University of Minnesota, and Autometric, Inc.

Problem Description

To properly understand the rational behind interfacing an expert system to a GIS, it is necessary to understand the type of work performed on the Nicolet. The Nicolet National Forest is located in Northern Wisconsin, where the predominate tree types are hardwoods and pines. The management of their aspen resources is of unique concern due to aspen's high value for timber production and wildlife (deer and grouse) habitat (Perala,1977). Deciding whether to manage an aspen stand for timber, wildlife, or even to manage it at all, requires knowledge contribute by a number of experts. These experts include professionals in the fields of silviculture, wildlife management, pest management, and soil science. Traditionally these experts evaluate the site characteristics of an aspen stand and recommend a particular management action based on their intimate knowledge regarding the relationships between site characteristics and subsequent stand production. For instance, a small aspen stand containing young trees growing on average soils far from an access road should be managed for wildlife, while a much larger stand should be managed for timber. These types of relationships can be formulated into "if-then" rules, which can be incorporated into a rulebase residing in an expert system.

The vast majority of aspen management rules make use of relationships which are spatial in nature, such as stand size, spatial distribution, proximately to roads, underlying soil types, etc. This spatial information can be obtained from conventional analysis techniques using geographic information systems. Currently the Nicolet National Forest is using the public domain GIS, known as MOSS, to perform such spatial calculations and analysis (Anonymous, 1984).

ASPENEX automates the analysis of site characteristics by intergrating the knowledge in an expert system with the analytics of MOSS. The rules, used in the expert system, were developed with the assistance from aspen management experts, who work on the Nicolet. MOSS was modified to accept very specific data exchanges between it and EXSYS. Communication software was developed to pass data and instructions between the personal computer and Data General. Initiation of the system occurred on the personal computer by running a program which controls and orchestrates the activation of the communication software. This in turn activates MOSS programs on the D.G. where spatial analysis are performed and creation of a file containing the necessary aspen site characteristics. This file is transferred back to the personal computer were it is analysised by expert system's rulebase. A final report is generated prioritizing the recommended management options based on the site characteristics. This file is used by the forest manager to assist in the final management actions for the aspen stands.

## SYSTEM DESCRIPTION

### Hardware Configuration

The Nicolet National Forest operates a Data General (DG) MV/8000 in the Forest Supervisor's office. The District Offices have the capability to network off this computer. The DG computer was originally procured for office automatic functions, thus other application software operation on the DG are not encouraged. Yet the access to personnel computer are nevertheless becoming more commonplace, which is helping to distribute to usage of central computer processing time. The development of ASPENEX was designed to take advantage of this current hardware situation. ASPENEX performs the bulk of its calculations on a personal computer, accessing the DG only when necessary.

### Software

ASPENEX is composed of four major software components; Geographic Information System, Expert System, Communication, and Control. Each component is described in detail in the following sections.

### Geographic Information System:

In 1982, the public domain Geographic Information System known as MOSS, was installed on the Nicolet National Forest's DG. Since then over 20 different themes of spatial information have been digitized for spatial analysis using MOSS. These themes comprise the spatial information required for everyday forest management and long-term forest planning. The themes in the MOSS database includes, but are not limited to, timber stand

maps, soil types, transportation, hydrology, wildlife and pest information, and land ownership. It is estimated that this MOSS database requires over 100 megabytes of disk storage. Currently the Nicolet uses of MOSS include pest management, grouse habitat identification, forest planning, etc. (Anonymous,1984).

ASPENEX takes advantage of both the digital spatial database and the spatial analysis capabilities offered by MOSS. The MOSS database is encoded so that each map feature (i.e. tree stand) is uniquely identified by its primary attribute or subject (i.e. stand type). The feature subject can be used to sort and select map features containing the search criteria. Further analysis of the data can be performed using MOSS functions, such as area calculations, proximity determinations, etc. MOSS analysis functions are modular, so that very specific information can be obtained from the database. For example MOSS can identify all mature aspen stands larger than 40 acres which are growing on good soil, yet are within an half a mile from an access road. ASPENEX makes use of these types of retrievals.

Expert System. In the last few years a number of expert system shells have become commercially available for expert system development and applicabtion. ASPENEX uses one such shell known as EXSYS. EXSYS was selected because it requires minimal trainning, it operates on most personal computers, and it allows for inter-program communication, such as with MOSS.

Communication. The existing hardware/software configuration placed the GIS and data on the Data General and the expert system on the personnel computer. In order for ASPENEX to automatically query and transfer data between MOSS and EXSYS, communication software was developed. Communication software handled all inter-machine transfer of data, as well as initiation of program execution on the different computers.

Program Control. The execution and control of the various components of ASPENEX were orchestrated by a control program running on the personnel computer. This program performed a number of different functions to assure proper operation of ASPENEX. These functions included the following:

- User interface
- Formating of data
- Execution of ASPENEX components
- Error checking

## SYSTEM OPERATION

### Rule-Base Creation

A primay consideration for selecting EXSYS was its ease in its operation of the rule-base creation, both of which are well documented (EXSYS, 1985). The building of the rule-base, the knowledge-engineering process, involved searches of available public knowledge and extraction of the private knowledge from recognized experts in management of aspen resources (Graklandoff, 1985).

The final recommendation for aspen management can be one of three actions. These actions are: manage the stand for wildlife, manage the stand for timber, or do not manage the stand at all. Deciding which action to take, requires information on the tree stand, as well as nearby associations. Typically the site characteristics include, stand age and density, stand size and species type, underlying soil, distance to access roads, and spatial distribution of related stands. The management action for each stand is judged separately based on the stand's site characteristics. The relationship between action and site characteristics is determined from the knowledge-engineering process. Each variable (site characteristic) has associated with it a relationship for each management action. From this relationship, ASPENEX calculates a value which indicates the possibility, between 0 and 100, for recommending that action. These relationships were determined based on the knowledge found in published sources (Basham 1958, Perala 1977, Shields etal. 1981, and Walters 1982), as well as from personnel interviews with Aspen experts. Depending on all the site characteristics, the final possibility will determine the final recommendation. The final possibility is calculated from the average of all individual possibilities.

### Spatial Analysis

The method in which ASPENEX determines the site characteristics is through the execution of MOSS functions using the Nicolet spatial database. As mentioned in the previous section, information pertaining to, stand type, stand size, soil type, and distance to roads were all necessary before recommending a management action. This information is spatial in nature, thus can be derived from the MOSS geographic information system.

### ASPENEX Output

Final output from ASPENX is in the form of a report summarizing stand characteristics derived from MOSS and final composit score calculated by EXSYS using the stand information (Table 1). Each stand has associated with it three scores, between 0 and 100, which correspond to the

management action, timber production, wildlife habitate, or ignore. The type of management favored is based on the highest score from EXSYS. The composit score is calculated using the average of all the individual values when the rules were found to be true.

The output report can be further evaluated and summarized in database management system a statistical package. The data can also be transfered back into MOSS for creation of a map identifying and locating those stands recommended for a particular management action.

**********

Table 1. Example of report generated ASPENEX. "Possibility of Management" values calculated by expert system using spatial information provided by geographic information system.

**********

| Stand ID* | Area | Soil Code | Prox. to Road |
|---|---|---|---|
| 02219016913 | 35.35 | 2 | No |
| 02221003913 | 24.75 | 2 | Yes |
| 02220002122 | 121.44 | 5 | Yes |

| | Possibility of Management | | |
|---|---|---|---|
| Stand ID* | Timber | Wildlife | Ignore |
| 02219016913 | 64 | 82 | 35 |
| 02221003913 | 71 | 73 | 21 |
| 02220002122 | 64 | 57 | 30 |

*Stand ID contains information on type and size of trees within stand.

**********

## SUMMARY

ASPENEX is a prototype system developed to assist in the forest management of aspen on the Nicolet Naitonal Forest. ASPENEX intergrates an expert system with a geographic information system. The expert system provides the rules required to manage aspen, while the geographic information system provides spatial information on the characteristics of the aspen stand. The spatial site characteristics are automatically passed to the expert system, where the data is analyzed using

the rulebase created by the aspen experts. ASPENEX is currently being used by the Nicolet National Forest and enhancements are being made to the system for application to other management concerns.

## ACKNOWLEDGMENTS

The author to thank William White (USFS), Laura Umland (Nicolet National Forest), John Davidson (Autometric, Inc.), and Bill Turner (Autometric, Inc.) for their valuable support. This work was supported through a cooperative project between the U.S. Forest Service, University of Minnesota, and Autometric, Inc.

## REFERENCES

Anonymous, 1984. Use of Map Overlay and Statistical System on the Nicolet National Forest. Unpublished report on file at Nicolet National Forest, Rhirelander, WS. pp.13.

Burrogh, P.A. 1986. Principles of Geographical Information Systems for Land Resources Assessment. Clarendon Press, Oxford. pp. 193.

Basham, J.T. 1958. Decay of Trembling Aspen, Can. J. Botany, 36:491-505.

EXSYS, Inc. 1985, EXSYS Expert System Development Package. Albuquerque, NM. pp.86.

Graklandoff, G.A. 1985. Expert System technology Applies to Contographic Processes-- Considerations and Possibilities. Presented at Fall 1985 ASPRS Conference-Indianapolis, IN. , pp. 613-624.

Perala, D.A. 1977. Manager's Handbook for Aspen in the North Central States. USDA Forest Service, N.C. Forest Exper. Stat. General Tech. Report NC-36. pp. 30.

Shields, W.J. and J.G. Bockheim. 1981. Deterioration of Trembling Aspen Clones in the Great Lakes Region. Can. J. For. Res. 11:530-7.

Walters, J.W. 1982. Evaluation of a System for Predicting the Amount of White Trunk Rot (Phellinus Tremulae) in Aspen Stands. Unpublished report on file at U.S. Forest Service, Forest Pest Management St. Paul, MN Field office. pp.7.