Surrey now has a base which is reliable and accurate. One base map is available for all applications regardless of scale and provides flexible plotting and reporting options. As well, geographical data can be located by specifying unique attribute data such as a plan number, an address or a road intersection.

Beyond the Base Map
The completion of the base is just the beginning. It is the foundation on which to build many more "stories" of data.

Information which is now on the mapping system includes 66 500 addresses and 820 km of sanitary sewer mains and 41 000 connections. In addition, the conversion of the water distribution system is 75% complete and some planning data such as zoning, Official Community Plan designations and concept plans are being automated.

The Future
Surrey's implementation of a GIS is now in the 'pilot project' phase. The availability of a solid, reliable digital base allows a significant area to be used in the pilot project. In the mapping project, the work of level content and definition had been done. This work was a good starting point for the design of the GIS data model. Also, with the majority of the high priority data sets either completed or almost completed, GIS can be functional as soon as the pilot is complete without any additional data input.

Conclusion
An estimated 80% of all data required and managed by a local government is geographically related. Effective management of this data so that it is available to the appropriate people, in the correct format and in a timely fashion, requires sophisticated tools beyond those of a draftsman and a sheet of mylar. Confirm the location of lot corners. The transition from a manual to an automated mapping system is time-consuming, costly and fraught with difficulties. In Surrey's case, the key to success was PLANNING. By observing the following guidelines, Surrey paved the way for a successful system implementation:

- plan early and in detail,
- plan for today and keep as many future options as possible. Coordinate geometry would still be our method of input if we started again,
- involve people from all levels of the organization. An excellent relationship between those responsible for data input and the programmers was a tremendous help,
- establish achievable goals,
- move slowly; build as you go; experiment; find the best paths to follow,
- over-manage at the start, and
- plan user friendly systems as tools for people.
Case Study: City of North Vancouver GIS

Bev Franks
City of North Vancouver
North Vancouver
British Columbia

Abstract
This presentation will describe the implementation, current use and future plans for GIS in the municipality.
Mapping California's Urban Forests

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Abstract
Over the past five years, Golden Coast Environmental Services, Inc. (GCES) has inventoried over 500,000 trees. GCES is an urban forestry information management firm specializing in street and park tree inventories for municipalities. Recently, GCES has seen a greater number of municipalities integrating this data with Geographic Information Systems (GIS).

Infrastructure elements have been a key concern in most systems; however, trees are often excluded. With a diversified staff of urban foresters and information systems specialists, GCES has shown the benefits of including tree data as a layer of information in GIS projects. Analyzing tree data against damage to sidewalks, presence of utilities and signs has been a great aid in municipal management.

GCES has used its urban forestry staff to develop a database of trees for over 30 communities throughout the State of California, four of which have been integrated with a GIS. The data has been collected for use in three different systems (ARC/INFO, INFORMAP III, and MAPINFO) for geographical information management.

This paper covers the following project elements: requirements analysis, GIS environment, database design, data collection, GIS integration and implementation. Benefits and drawbacks of the different projects will be discussed.
Background
A well managed tree population is a valuable community asset. Special attention is required to sustain a forest in today's urban environment. At the same time, increasing costs for public safety and welfare relative to tree care heightens the need for tree managers to become informed.

Golden Coast Environmental Services, Inc. (GCES) has linked managers responsible for tree care to the power of modern data management insuring proper care for urban trees. GCES has worked with numerous agencies in developing effective tree inventory and management systems. The detailed inventory produces the data necessary to obtain a precise evaluation of existing conditions. Combined with a well designed tree record keeping system, the inventory provides the means for automated tree management.

The automated system was designed to help today's urban forester accurately evaluate present needs, anticipate future projects, document schedules and performance to maintain public health and safety, and properly budget available funds. The GCES automated management system meets the challenge of modern tree resource management. Four such projects have been integrated with a GIS. The cities of Irvine, Rancho Cucamonga, Santa Ana & Santa Barbara, California have GIS projects of different sizes, but have all incorporated tree inventory data.

Requirements Analysis
The requirements for an urban tree inventory differ from natural forest inventories, the major factor being the environment. Urban trees have been taken from their natural environment and subjected to harsh punishment. Concrete, cars and utility lines all prohibit natural tree growth in urban areas. To collect data which is useful for urban tree management, advanced planning is required.

With five years of experience inventorying urban forests, the requirements are now becoming standardized. However, the process is still used to clarify the exact needs of each project. There are five main categories of data collected: location, species identification, physical characteristics, maintenance classification, and environmental conditions.

Each of the cities in the four sample projects used the experience of a consultant to develop the requirements for their tree inventory. Since a standard has been developing by GCES, this phase of the project was very simple yet critical. Beginning a project without the assistance of experienced professionals is the greatest cause of failure. Most municipalities who have attempted a tree inventory without assistance don't have a program which works.

A requirements document should be written during this phase of the project. It will serve as a great tool in requesting proposals for work. The documentation can also be used for assessing progress and the completion of goals. Without proper documentation, your goals will unknowingly change and lead to your dissatisfaction with the final product.

GIS Environment
The hardware required to operate a GIS often exists before selecting the software. In three of the four sample projects, the hardware and software were selected before the tree inventory began. In the other project, there was no GIS in place and a PC-based program was implemented with the tree inventory as the initial layer of data.

The cost of workstations cannot be ignored when discussing GIS projects. A workstation can cost anywhere from $7000 and up. The three projects which were running their GIS on a minicomputer were limited to between 1 and 10 workstations throughout the city, due to cost. This required Management Information Services (MIS) staff to be in charge of processing needs for departments.

Relying on MIS for all GIS needs has caused a slower turnaround time for maps and other requests. However, in some cases, departments were relieved by not having to learn how to use the GIS. The PC-based GIS was used by the urban forester, not MIS. This required very user friendly software. The PC-based program was able to offer this.

Infrastructure data was the primary selling point for incorporating tree inventory data in the GIS. The three systems which were in place at the time of the inventory had underground utilities, water lines, electrical lines, streets, sidewalks, assessors data and parcel lines digitized. Trees were the first animate layer of data included in the system.

<table>
<thead>
<tr>
<th>Table 1. Tree Inventory Data Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Address</td>
</tr>
<tr>
<td>Street</td>
</tr>
<tr>
<td>Tree #</td>
</tr>
<tr>
<td>GIS #</td>
</tr>
<tr>
<td>Species ID</td>
</tr>
<tr>
<td>Botanical Name</td>
</tr>
<tr>
<td>Common Name</td>
</tr>
<tr>
<td>Physical</td>
</tr>
<tr>
<td>Diameter</td>
</tr>
<tr>
<td>Height</td>
</tr>
<tr>
<td>Canopy Spread</td>
</tr>
<tr>
<td>Vigor</td>
</tr>
<tr>
<td>Condition</td>
</tr>
<tr>
<td>Environmental</td>
</tr>
<tr>
<td>Growspace Size</td>
</tr>
<tr>
<td>Utility Presence</td>
</tr>
<tr>
<td>Hardscape Damage</td>
</tr>
</tbody>
</table>
In each of the projects, the inventory data was to be used by a separate application. This would be for daily retrieval and updating. In two cases, the inventory data was distributed on another computer. In these cases, the GIS updates a copy of the data on a periodic basis, as needed.

**Database Design**
The design of the database in each of the projects has been determined by an existing and separate application. TreeKeeper, GCES's tree management software, is used to update the tree inventory while tracking work histories and citizen-generated work orders. In three of the four projects, the data is stored on a PC in a dBASE file format. In the other project, the data is on the GIS host in an ORACLE format.

The primary use of the tree data was for TreeKeeper. This required a special interface to the GIS. This has been done through a key field in the tree database. The field has been named gis# and stores a unique number for each record. This same number is stored in the GIS datafile for trees. This key field is used for updating information from TreeKeeper to the GIS. This approach has been used in two of the four projects.

Data redundancy is an issue which MIS managers love to resolve. The above example gives them an opportunity for that in the future. In the other two projects, an individual database has been used and shared by both systems. One project has a minicomputer as the host and the other has a PC. Sharing the same datafile between the two applications can only happen if the GIS and the tree management program store and read data in the same format.

Address matching and physically digitizing trees are two options for uploading tree data to the GIS. In the PC-based GIS, trees were geo-coded; this function matches and assigns records by address. This is not a process to be used by someone who requires an exact physical location of the trees on maps. However, it is much less time consuming than digitizing.

There are many reasons why exact physical locations are not necessary for trees. Trees have root systems which cannot be predicted or surveyed. The location of a tree trunk above ground does not preclude it from being suspected of causing damage to a sidewalk 40 feet away. A tree whose location is digitized to an accuracy of 1 inch would not be of benefit even a tree expert in determining whether tree roots are the cause of the damage. The tree's crown can be as devious as its roots. This is something that is too dynamic to update in a GIS. Pruning can reduce the crown spread by 50% and new growth will increase it within months.

However, above ground interference with utility lines and landscape design are important reasons to have the trees digitized as opposed to address matched. Through our experience, we have found that the tree data is not going to be used for precision work. Maps for tree care contracts are the greatest use of GIS in urban forestry. The contracts list the addresses of trees from the inventory and don't require precise plotting.

**Data Collection**
Tree inventories are traditionally taken by horticulturists walking the streets and entering data into handheld computers. Addresses and street names are collected for identifying the location of the trees. A tree number is also given to trees because multiple trees can exist at an address. This is the extent of location data necessary for address matching with the GIS.

In systems which will digitize the exact location of the tree, base maps are used for plotting trees in the field. A dot is placed on the map in the location of the tree. A sequential number is given to that record of information. Each number does not need to be recorded on the map since they are sequential. However, when corners, are turned the current number should be recorded to note the change of direction. If there are long blocks of trees, every 20th number should be recorded. The trees are later digitized as a layer of information in the GIS. When tree plantings are linear, inventories are taken up one side of the street then down the other. In urban forest inventories, 90% of the trees are planted this way. The other 10% are planted in open areas like parks. In open areas, inventories are more difficult.

![Figure 1. Typical Urban Tree Inventory Map](image_url)

A divide-and-conquer strategy is implemented in open space tree inventories. Base maps are used to divide the area into smaller units using either physical reference points as dividers or setting up a grid based on measurements. Once units are created, each one is inventoried based on the data collector's own direction.

The tree inventories which include GIS numbering have slowed down data collection. In addition to increasing field inventory time, digitizing extends the timeline for integrating the data.
GIS Integration

In the projects which plotted trees, the first step of integration was digitizing. Only one field of each record was added during digitizing. The GIS number was input to link the tree inventory database. An algorithm should be used to increment and assign sequential numbers to each tree as it is digitized.

In two cases, duplicate databases are maintained on different systems in different formats. The data is needed and used on a daily basis for tree management on a PC; the data is needed and used less frequently with the GIS on another computer.

In distributed situations, to access the tree inventory data, an ASCII export-import routine is written. The tree management application exports the data to ASCII format. The GIS then imports the most current database into its own format. This results in two copies of the same data. The import routine searches on the key field and copies each record of data.

In the other two cases, the same database is shared by both applications. In one case, the GIS use of the data did not require a level of accuracy any greater than by address. Integrating the tree inventory was a one-step process. Each record was assigned an X- and Y-coordinate by address. In the other case, each record was assigned an X- and Y-coordinate by matching the GIS number with the point which was digitized. This was a two-step process: digitizing and coordinate assigning.

Since address and street are standard fields of data collection in tree inventories, address matching can happen at anytime in the future without any advance planning. The integration is also easier when the datafile is shared by the GIS and the tree management program.

Implementation

The step of digitizing the trees from base maps was the largest obstacle in implementation. The amount of work was overwhelming to the responsible parties. The MIS department was not usually interested in allocating staff for the project. The tree department did not have the staff which they could afford to assign to the project. Since the tree department had the greatest need for the data, they ended up digitizing.

The greatest use of tree data within the GIS has been in contracting. An urban forest manager can now easily plot all the tree locations which require maintenance. The ease in changing geographical parameters allows the manager to quickly redraw boundaries to determine the balance between work needed and funds available.

Analyzing damage to hardscape caused by trees can pinpoint species to target for removal. Displaying each species in a different color makes an effective presentation. In areas where spraying is needed for pest control, a GIS can quickly display areas which are most densely populated with the target species.

The urban tree inventory is an important management tool. The use of GIS will increase its effectiveness. In prior years, the often-neglected tree budget has excluded costly GIS. With the decreasing costs of technology and the increased awareness of information sharing, municipal management will be planting more trees in their GIS.

Conclusion

After integrating four tree inventory projects with geographic information systems, some conclusions have been made on methods used to complete these projects.

1. A GIS is not intended for day-to-day tree management.
2. A GIS is a great tool for geographic data analysis.
3. Plotting trees on base maps and digitizing the locations is not necessary for most GIS uses of tree data.
4. Address matching is the most cost effective means of integrating tree data with a GIS.
5. Tree inventory data is capable of integration with GIS at any time.
6. Integrating tree data and a GIS is preferred by sharing files with the tree management program.
Issues in Acquiring GIS Hardware and Software

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Abstract
Municipalities considering the acquisition of a Geographic Information System (GIS) are faced with many complex issues. Making an optimum choice depends on a sound understanding of the hardware and software alternatives available, as well as an appreciation of technological trends. This paper describes and explains what these trends are and how they affect the implementation of GIS.
Introduction
GIS is defined as a system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced data for solving complex planning and management problems. Other related systems which deal with spatial data are automated mapping and facilities management (AM/FM) and computer-aided design (CAD) for engineering applications.

Although software products exist which address these needs separately, the trend is toward GIS which incorporate all the required functionality in one package. Generally, the choice of appropriate hardware follows the selection of software.

Users should be aware, however, that many GIS have evolved from either a CAD or an analysis perspective and may be optimized for particular functions. Understanding your needs and the capabilities of these systems is crucial.

Other issues which influence system selection are the organization's structure, plans for growth, the need to interface with existing business data, and system cost.

Hardware and Software Trends
In order to make an informed system selection, one should be aware of the major hardware trends and software technology. Some of these trends are the move to workstations, RISC processors, relational databases, UNIX operating systems, windows, distributed databases, distributed processing, and local area networks.

Early geographic information systems were minicomputer and mainframe based since only these systems could provide the required computational power and data storage capacity. Access to the system was provided through expensive graphics terminals.

Unfortunately, the intensive computational and data transfer characteristics of GIS tended to negatively impact the performance of other host-based applications. Vendors realized the need to off-load spatial processing.

Vendors also realized that being tied to a particular proprietary architecture limited their market for GIS. Greater acceptance of GIS depended on finding lower cost generic system platforms. The answer appears to be powerful workstations and, to a lesser extent, microcomputers. Figure 1 shows the growth trend of the various GIS platforms.

Determining which platform is appropriate for your use requires an understanding of their technical and functional differences.

Although workstations are inherently able to handle 2D and 3D graphics, the microcomputer requires considerable upgrading. Most GIS vendors recommend a '386' chip plus additional memory in the order of 5Mb, a fixed disk with a capacity of approximately 100Mb, a math co-processor, a graphics video card, and a high resolution color monitor. A Macintosh II microcomputer can also be expanded in a similar fashion.

If the microcomputer is part of a network, then a LAN card and software are also required. You can expect to pay approximately $25,000 for such a configuration. This price overlaps that of many low-end workstations.

In comparison to the expanded microcomputer, a representative low-end workstation would include a 19 inch monitor with higher resolution graphics, a 150Mb fixed disk, 6Mb of memory, and hardware and software necessary for a network interface.

An increasing number of workstations come equipped with the Reduced Instruction Set Computer (RISC) chip. This technology is based on a simplified instruction set that provides increased performance at a lower cost. The power of workstation processors is in the range of four to 25 MIPS (million instructions per second) compared to three to five MIPS for our sample microcomputers. Table 1 compares the technical features of the microcomputer and workstation.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Microcomputer</th>
<th>Workstation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microprocessor</td>
<td>Intel 80286, 68036</td>
<td>Proprietary RISC</td>
</tr>
<tr>
<td>Power</td>
<td>3-5 Mips</td>
<td>4-25 Mips</td>
</tr>
<tr>
<td>Memory</td>
<td>2-5 Mb</td>
<td>6+ Mb</td>
</tr>
<tr>
<td>Graphics</td>
<td>640 x 480 to 1024 x 768</td>
<td>1184 x 884</td>
</tr>
<tr>
<td>Resolution</td>
<td>MD-DOS, OS/2</td>
<td>UNIX</td>
</tr>
<tr>
<td>Operating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>20-25 K</td>
<td>25 K+</td>
</tr>
</tbody>
</table>

Microcomputers are still appropriate for GIS where workstation features are not required and particularly for stand-alone operation situations.

We can expect the distinctions between microcomputers and workstations to blur as microcomputers extend their power upward and workstations provide greater functionality at lower prices. Evidence of this is the increasing usage of UNIX on microcomputers.

The majority of workstations use the UNIX operating system. UNIX is part of the 'open system' strategy which allows users to mix and match applications programs from various vendors. Theoretically, it should be possible to run an application program written for UNIX on any vendor platform that supports the UNIX operating system. Users are no longer locked into purchasing software for a particular proprietary system.

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Estimated Sales of GIS & Mapping Computer Systems

**FIGURE 1**

- Workstations
- Host-based stations
- Personal computers

Source: Dataquest, April 1989
The advantages of UNIX over the MS-DOS operating system are support for virtual memory, multi-tasking, multi-user, and file management and protection. Table 2 compares the functional features of microcomputers with workstations.

Table 2. Functional Feature Comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>Microcomputer</th>
<th>Workstation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Memory</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-tasking</td>
<td>No (OS/2: Yes)</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-user</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>File Management</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Protection</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Virtual memory allows the system to run programs too large to fit into memory. Portions of programs not in use are temporarily swapped to disk. This is a valuable feature since GIS programs tend to be large. MS-DOS and OS/2 operating systems do not provide this facility.

Multi-tasking is the ability to run more than one program or operation at the same time. This feature permits a database query or a time-consuming batch function, such as a plot to be done at the same time as graphic data are being displayed. The user interface to multiple tasks is often handled by a windowing program, which provides a consistent user view of each task. This improves productivity and requires less training to learn how to use applications.

MS-DOS does not support multi-tasking. Windowing on microcomputers gives the illusion of several ongoing tasks, yet, in fact, processing is suspended on all but the current window. OS/2 will give microcomputers true multi-tasking capability.

The multi-user feature allows more than one user or operator to utilize the processing resources of a particular workstation at the same time. This permits a query to be passed to a remote workstation that has the required data layers in its disk storage. The query will be handled simultaneously with other user processing.

Distributed Databases and Processing

The goal is to provide all users access to data anywhere in the network without the user requiring the knowledge of where the data physically resides. The implication of a distributed database means that the system can be configured to conform to the organization and allows the delegation of responsibilities for data. For example, the Planning Department would maintain zoning and community plan layers on their workstations, while Engineering would maintain infrastructure layers, and Finance would maintain property and assessment layers. These departments will be responsible for maintaining their respective map layers, yet they are available throughout the network to other users.

The use of workstations not only supports distributed databases, but also distributed processing. This allows additional processing capacity to be added incrementally to accommodate more users without degradation in the performance of the system. The functionality of GIS can be distributed among users according to their needs. For example, some workstations can run programs for data editing, others may have CAD, and still others programs for data analysis.

Since workstations allow distributed processing and distributed databases, file management and protection becomes a more complex problem. Responsibility for maintaining and managing portions of the database must be clearly understood. The UNIX operating system provides the system manager with the ability to set controls on who can access, add, or update data.

Although both microcomputers and workstations are capable of communicating over a local area network to access files, there is a significant difference in the way in which this is accomplished. In a network of microcomputers, data are located on a central server machine, and data stored on other microcomputers are not available to users on the network. Workstations have the advantage of peer-to-peer communications. Peer-to-peer communications allows any workstation to communicate directly with any other workstation in the network. This feature supports the distribution of data to multiple locations.

Distributed Geographic Information Systems require communications networking software to link together systems which host the attribute data, workstations, and peripherals such as plotters, scanners, and digitizers. Standards for this software have emerged and are being used by most GIS vendors. Examples of these standards are TCP/IP and NFS.

TCP/IP is the foundation communications protocol upon which NFS and other network tools are built. NFS supports transparent access to files on other disks located throughout the network. With these communications tools in place, data and processing can be distributed across the network even if users are utilizing different kinds of hardware.

The benefits of these workstation features are improved productivity and greater data integrity, particularly in networked environments.

Interfacing GIS to Business Data

The shift toward workstations and microcomputers has achieved the goals of lower cost and wider market appeal for GIS. At the same time, it has introduced greater complexity in interfacing these GIS with host-based business data. The situation is complicated by the fact that most workstations use UNIX, whereas most municipal business applications run on other proprietary operating systems.

Many users see the capability of interfacing spatial data with existing business data as a major benefit thus justifying the use of GIS. This capability facilitates such operations as re-
trieving name and address data from a property file in order to generate notices to property owners within so many meters of a planning project, or displaying the location of dangerous goods and sprinklers for a commercial building.

Data in the business systems are often organized in sequential and indexed sequential files or in hierarchical databases, whereas the vendors have chosen to link to relational databases. Relational databases offer tremendous flexibility in managing data. New data tables can be added and relationships can be defined on the fly at the applications level instead of at the database system level. Thus, it is not surprising that virtually all GIS vendors have developed interfaces to link spatial data with attribute data stored in relational databases.

Users have the choice of either developing custom interfaces to existing files and databases or converting their data to a relational database. Neither of these options are trivial or inexpensive tasks.

If your business database resides in a relational database, your interfacing job is made easier. Many GIS vendors have developed the required interfaces or, alternatively, they can provide toolkits with which interfaces can be developed.

In summary, the acquisition of a Geographic Information System requires an appreciation of technological trends. These trends definitely affect the way in which the GIS can be used. Intelligent choices will facilitate greater data access and integration with the organizations' business systems.
Special Interest Group

Session G5
Artificial Intelligence

A Neural Net Model for Forest Management

Artificial Intelligence and GIS: Tools to Implement Adaptive Resource Management

Natural Language Interface to Geographic Databases

Automated Labelling System for the Alberta Vegetation Inventory Project
A Neural Net Model for Forest Management

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Abstract
The establishment of a 'smart' computer package for effective data processing and forest resource analysis will facilitate sound decision making concerning the multiple use of forest lands. Neural net technology has been studied for many years in order to achieve human-like performance in fields where problems were unlikely to be solved efficiently using traditional methods. A computer software simulation of such a net was developed and an empirical analysis was undertaken for the Peace River Timber Supply Area (TSA) in British Columbia to demonstrate the capability of the model for forest land management.
Introduction

Today, public forests are managed to provide society with various goods and services such as timber, forage, wildlife habitats, recreation and other environmental and ecological functions. The concept of multiple forest land use is now accepted as a sound and viable forest management policy (BCMOLP, 1984). Multiple forest land use needs to allocate forest lands to meet several demands, aspirations, and desires of society with the constraints of certain biophysical and socio-economic conditions. The establishment of a computer package for effective data processing and forest resource analysis will facilitate sound decision making concerning the multiple use of forest lands.

Neural net technology has been studied for many years in order to achieve human-like performance in fields where problems were unlikely to be solved efficiently using traditional methods. A neural net is composed of many nonlinear computational elements (neuron) operating in a parallel manner. These neurons are connected with weights that are adjustable during the learning process which takes place to improve the performance. This technology, with a large processing capacity, can perform various tasks for information classification and pattern identification. Here, information involving uncertainties and fuzziness is accepted and approximate results will be output if they satisfy the manager’s requirements. If the results are not satisfactory, the net needs to be retrained (Lippmann, 1987). Neural net modeling or forecasting operates in a parallel fashion in contrast to an expert system which adopts a sequential approach (Klimasauskas, 1989).

The purpose of this paper is to apply neural network technology as a decision support for forest resource planning in an attempt to bring it to the attention of resource analysts and planners. A computer software simulation of such a net was developed to test the capability in multiple forest land use management. Specifically, an empirical analysis was undertaken in the Peace River Timber Supply Area (TSA) of British Columbia to demonstrate the capability of the model for forest land management.

Background

Given the finite land resource base of British Columbia, there are uncertainties regarding the ability of the land to meet expected demands for forestry, agriculture, wildlife, recreation, and many other uses. One pressing problem in land use planning is to resolve whether a tract of land should be allocated for wilderness preservation or used for timber production. Society’s choice of the use of land resources reflects a complex set of interrelations involving biophysical, social, and economic factors on both the demand and supply sides of the land use equation. Among these are the quantity, quality, land location, current land use, economic rent of the land, technology and management skill, and other social and political factors such as government policy and public perceptions toward wilderness preservation. How to allocate land resources effectively among multiple uses to meet various demands remains a critical issue (BCMOLP&H and BCMOF, 1981). Operation of land use planning will be facilitated by systematic analysis. It is obvious that more promising and effective analytical tools are desirable for resource analysis. Advances in computer technology have increased the design and use of computer-based decision support systems in land resource planning (Fabos, 1985; Buongiorno and Gilless, 1987). The development of computer software which is an essential part of the new analytical tool, can significantly improve current land use planning practices. These practices aim at selecting a desirable land use from a range of feasible options on the basis of a set of relevant evaluation criteria.

The General Framework of Neural Net Model

The basic structure of a general Neural Net Model (NNM) is described in detail by Rumelhart et al. (1987a), through a set of components and rules which are classified into eight major aspects:

1. a set of processing nodes,
2. a state of activation,
3. an output function for each node,
4. a pattern of connectivity among nodes,
5. a propagation rule for propagating patterns of activities through the network of connectivities,
6. an activation rule for combining the inputs impinging on a node with the unit’s current state of that node to produce a new level of activation for the node,
7. a learning rule whereby patterns of connectivity are modified by experience, and
8. an environment within which the system must operate.

The broad structure of the general NNM is essentially a set of relationships between various processing nodes which represent different factors. These relationships are expressed in mathematical formulations which, due to lack of space, are not described here. More detailed information regarding the structure of the NNM can be referred to Rumelhart et al. (1987a).

Study Area

In accordance with the problem of conflicting land resource uses indicated by existing reports and documents (both private and public) and expert opinion, this study examines two specific problem areas. Figure 1 presents the study area.

![Figure 1. The Sub-Region of the Peace River Region](image)
areas. The first study area (Area I) is part of Townships (TP) 85 and 86, and Range (R) 17, which is located east of the Beaton River. Lands in this area are mostly classified as high value woodland for forestry (BCMOLP&H, 1985). The second area (Area II) located further east represents a mixture of land uses including wetlands, preserved areas, forests and farmlands.

**Data Requirements**

The collection of data which incorporates various data sets from different sectors such as agriculture, forestry and environment, is a necessary step for land resource planning. Information about land resources, current land uses, and land use alternatives in the Peace River Region of British Columbia is available from a wide range of sources. However, comprehensive land data bases with a wide array of land use categories are uncommon. The existing land resource data sources tend to focus on one use such as agriculture, forestry or wildlife. These data bases were established by each Ministry or individual agency for its own needs. Such data sources limit land resource planning because of inconsistencies in scale and coverage. Commonly, when several data sources are used, the variety of scales and mapping units used pose problems of compatibility.

If the data are identified spatially, it is possible to estimate the land resource availability with a defined capability class in any specific location (Manning, 1988). Land resource data can then be related to particular sites or land units. Organizing and incorporating different data sets spatially from different resource sectors (agriculture, forestry and wildlife) has been of considerable importance. The key point is to choose a suitable spatial framework which allows for the integration of information from diverse sources.

There are several approaches with respect to the use of spatial units for analysis. The first approach is the use of administration units for data portrayal and integration. One of the problems in the use of this type of unit is that only one administration unit existed in the Peace Region.

The use of ecological units (soils, climates, etc.) is another approach. There is significant biophysical information based on soil zones or climate zones available for the study region. However, socio-economic information is not always available on the same basis.

A third type of spatial unit is geometric grids where data are synthesized and reported by grids (sections or quarter sections). This approach is the most appropriate for this study. Information from various sources such as surveys, censuses, government agencies or ecological units can be modified to describe the grid units through the superimposition of various land resource maps. This procedure provides data with a broad array of land use categories.

In this study, the geometric units or map sections were used as the basic units for assessment. There were a total of 17 sections in the study area (see Figure 1); each section represents an unique area. Data on land resource availability, productivity, current land uses, yield, economic return, and habitat value for one section are different than those of another section.

**The Simulator and Results**

The experimental package was built on the Rochester Connectionist Simulator (RCS), version 4.1, which runs on the Unix environment and provides a graphic interface for Sun Microsystem workstations (Goodard, et al. 1989). This general purpose simulator (RCS) allows us to write C language code to construct the specific network connections and define the learning algorithm. We chose the standard sigmoid activation function and error-propagation function provided in the RCS Back Propagation Package. The learning procedure is firstly to use the input values to produce its own output values and then compare these outputs with the teaching values which were given by experts. If there were no differences, no learning would take place; otherwise, the weights were adjusted to reduce the differences (Rumelhart, et al. 1987b). The rule for changing weights used in this application was the generalized delta function, also provided in the RCS.

A neural net model which exhibits a hierarchical structure was designed. This model contained a multiplicity of land use planning by several land use objectives. Figure 2 illustrates the components and linkages of the model which consists of three layers: the input, hidden, and output layers. During the learning processing, an additional layer called the teaching layer was added for supervision purpose. This teaching layer contains the same number of nodes as those of the output layer.

At the input layer, there are 22 nodes, each of which represents a crucial factor which may affect land use decision making. Associated with each land unit are factors such as yields, net economic returns, soil erosion rates, habitat values, and areas of different land uses. Data on these factors for each land unit are required as inputs for the analysis.

![Figure 2. Structure of the Neural Net Model](image)

The hidden layer of the model consisted of 4 nodes reflecting four land use objectives. Land use planning is often characterized by multiple objectives which are frequently in conflict. The measurement units of these objectives are almost always incommensurable. In this study, the land use objectives included: net economic return, timber production,
habitat value, and soil loss by erosion. The objective functions were defined over these factors, which provided analysts with the required information to establish linkages between factor nodes and objective nodes.

In the presence of multiple objectives, one land unit which is suitable with respect to one objective may not be suitable with respect to another objective. For example, the attainment of economic return may sacrifice the attainment of the habitat protection objective. In multiple land use decision making, it is common that not all the objectives can be achieved simultaneously. Possible trade-offs or compromises between objectives have to be made in resource use planning (Cohon, 1978; Ignizio, 1982). These objectives are then used as decision criteria or standards by which the desirable land use option is selected for each land unit. This consideration provides the logical basis which links the objective nodes to the output nodes representing land use

Training patterns: Grid 2 for logging option; Grid 24 for preservation option.

<table>
<thead>
<tr>
<th>Trails</th>
<th>Logging Value</th>
<th>Preservation Value</th>
<th>Land Use Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>G26</td>
<td>323</td>
<td>675</td>
<td>*</td>
</tr>
<tr>
<td>G33</td>
<td>832</td>
<td>167</td>
<td>logging</td>
</tr>
<tr>
<td>G35</td>
<td>416</td>
<td>596</td>
<td>*</td>
</tr>
<tr>
<td>G28</td>
<td>569</td>
<td>439</td>
<td>*</td>
</tr>
<tr>
<td>Test 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G4</td>
<td>486</td>
<td>519</td>
<td>*</td>
</tr>
<tr>
<td>G3</td>
<td>427</td>
<td>576</td>
<td>*</td>
</tr>
<tr>
<td>G18</td>
<td>70</td>
<td>930</td>
<td>preservation</td>
</tr>
<tr>
<td>G25</td>
<td>133</td>
<td>868</td>
<td>preservation</td>
</tr>
<tr>
<td>G31</td>
<td>196</td>
<td>812</td>
<td>preservation</td>
</tr>
</tbody>
</table>

Training patterns: Grid 2 for logging option; Grid 24 for preservation option; and Grid 33 for logging option

<table>
<thead>
<tr>
<th>Trails</th>
<th>Logging Value</th>
<th>Preservation Value</th>
<th>Land Use Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>G35</td>
<td>627</td>
<td>378</td>
<td>logging</td>
</tr>
<tr>
<td>G3</td>
<td>669</td>
<td>335</td>
<td>logging</td>
</tr>
<tr>
<td>G4</td>
<td>808</td>
<td>195</td>
<td>logging</td>
</tr>
<tr>
<td>Test 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G33</td>
<td>921</td>
<td>81</td>
<td>logging</td>
</tr>
<tr>
<td>G31</td>
<td>296</td>
<td>705</td>
<td>preservation</td>
</tr>
<tr>
<td>G25</td>
<td>300</td>
<td>702</td>
<td>preservation</td>
</tr>
<tr>
<td>G24</td>
<td>34</td>
<td>966</td>
<td>preservation</td>
</tr>
</tbody>
</table>

Training patterns: Grid 2 and Grid 33 for logging option; and Grid 24 and 31 for preservation option

<table>
<thead>
<tr>
<th>Trails</th>
<th>Logging Value</th>
<th>Preservation Value</th>
<th>Land Use Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>G26</td>
<td>473</td>
<td>530</td>
<td>*</td>
</tr>
<tr>
<td>G31</td>
<td>495</td>
<td>509</td>
<td>*</td>
</tr>
<tr>
<td>G35</td>
<td>639</td>
<td>365</td>
<td>logging</td>
</tr>
<tr>
<td>G33</td>
<td>949</td>
<td>51</td>
<td>logging</td>
</tr>
<tr>
<td>Test 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G27</td>
<td>967</td>
<td>33</td>
<td>logging</td>
</tr>
<tr>
<td>G19</td>
<td>501</td>
<td>503</td>
<td>*</td>
</tr>
<tr>
<td>( after another 500 cycles )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G19</td>
<td>489</td>
<td>516</td>
<td>*</td>
</tr>
<tr>
<td>G13</td>
<td>240</td>
<td>763</td>
<td>preservation</td>
</tr>
<tr>
<td>G3</td>
<td>670</td>
<td>333</td>
<td>logging</td>
</tr>
<tr>
<td>G2</td>
<td>993</td>
<td>6</td>
<td>logging</td>
</tr>
<tr>
<td>G24</td>
<td>302</td>
<td>701</td>
<td>preservation</td>
</tr>
<tr>
<td>( after another 500 cycles )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G24</td>
<td>35</td>
<td>965</td>
<td>preservation</td>
</tr>
</tbody>
</table>

Note: G: Grid or Map Section; *: Uncertain

Table 1. Results of the Analysis
options. In this prototype study, the model structure was
purposely kept simple. Only two land use options, forest
production and wilderness preservation, were considered in
the analysis.

The procedure of operating the neural net model for forest
resource analysis began by training the net with a training
algorithm. Prior to the training, it was necessary to consult
with experts in forest resource management to identify two
land units within which land use patterns represent the two
typical options. In this case, map section 2 in area I and
map section 24 in area II were chosen as examples of the
two land use options.

Once the data files were set, input values were fed in
parallel to the net. The net was trained by selecting some
random weights and internal thresholds and then presenting
all training data sequentially. The training algorithm repeat-
edly adjusted the weights after every trial using side
information specifying the correct land use option until
weights converged. The net was considered to have
converged when outputs no longer changed on successive
iterations, and one output of the last iteration corresponding
the most likely land use option was high (maximum score of
1000), the other output was low (minimum score of 0). The
output was then used directly as the restored memory.

Data files for eight land units in area I and seven land units
in area II were presented for alternate trials, and the desired
outputs were either 1000 or 0. Results of the analyses are
listed in Table 1. All the outputs with input data files for land
units in area I except that for grid 26 exhibited higher
logging values and lower preservation values. These results
indicate that land resources in this area were desirable for
the forest production option. In grid 26, the forest production
option and the preservation option scores were relatively
close. This result could be attributed to the fact that many
forest lands have been converted to croplands. The actual
net outputs with inputs for area II show a different pattern,
with lower scores for forest production option and higher
scores for preservation option. Based on these results, most
land units in area II should be preserved for wilderness
area. Land use decisions for those land units with similar
scores in both the forest use option and the preservation
option are uncertain and require further investigation.

Concluding Comments
The preceding analysis with the neural net model has
illustrated the potential of this technique in multiobjective
forest use planning to generate alternative options. The
exercise was prototypical in that only a small number of
objectives and factors were specified and outcomes
analysed. The neural net model is in an early stage of
development. A more comprehensive analysis would
include a much greater range of objectives, land use
options or strategies, and factors affecting land uses.
Nevertheless, the neural net model developed in this study
provides a useful technique for forest resource manage-
ment. Surprisingly, there have been very few practical
applications of neural nets to date (Lippmann, 1987).
Resource analysts show a lack of awareness regarding the
potential of this technique for land use planning and man-
agement problems. Clearly, much more thought and effort
must go into refining and designing new models for re-
source use planning.

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Artificial Intelligence and GIS: Tools to Implement Adaptive Resource Management

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USA

Abstract
Adaptive resource management is a continual learning process that never converges to a state of equilibrium involving full knowledge and optimum productivity. In the design of adaptive management strategies, existing knowledge must be represented so that errors can be detected and used as a basis for further learning. In addition, the inherent uncertainty and risk surrounding possible future outcomes must be represented. Artificial intelligence techniques combined with GIS afford the opportunity to represent current knowledge and uncertainty. The blackboard approach to problem solving is reviewed. Blackboards provide a method to modularize and integrate various methods of representing knowledge, such as rules, cases, and models, along with representing uncertain knowledge. Because the knowledge about forestry and natural resources is often spatial in nature, a GIS should form the foundation of the blackboard. These concepts are being used in the design of a smoke management advisory system to assist in the planning and execution of prescribed burning operations.
Smoke Management
Prescribed fire is an indispensable part of forest management. It is used to treat approximately 6 000 000 acres (2 428 000 ha) each year in the South. Prescribed fire is used in the South to reduce hazardous fuels, dispose of logging debris, prepare sites for seeding or planting, improve wildlife habitat, manage competing vegetation, control insects and disease, improve forage for grazing, enhance appearance, improve access, and perpetuate fire-dependent species (Wade and Lunsford 1989). Yet along with the many benefits of prescribed fire, smoke is produced.

Smoke from a prescribed fire can adversely affect health, visibility, and highway safety. The risk is greatest from fires which emit large amounts of smoke for extended periods of time. Most understory prescribed burns and broadcast burns are 'self-extinguishing', that is, smoke sources are extinguished within a few hours of ignition. Thus, these prescribed burns tend to cause fewer problems than either piled debris burning or wildfires. Pile burning and wildfires can result in extensive smouldering combustion that provides a smoke source for many hours or days. A long-lived smoke source greatly increases the risk of encountering meteorological conditions which fail to disperse the smoke adequately, direct the smoke over populated areas and roadways, or enhance the probability of extremely low visibility in smoke and fog. Such conditions cannot be reliably forecast over periods greater than 36 hours. The risk of an errant forecast exists for even shorter time periods.

The results of decreased visibility on roadways from smoke, often in combination with fog, have occasionally been tragic. In November 1983, 3 people were killed and 7 injured in a highway accident involving forestry smoke on Interstate I-10 in the Florida panhandle. Those involved in the accident filed suit for $21 million. On December 31, 1988, forestry smoke was implicated as a cause of near-zero visibility along a 30-mile stretch of I-95 near the Kennedy Space Center in Florida. The result was 12 separate accidents involving 45 vehicles with numerous injuries but fortunately no fatalities.

Responsible forest management utilizes prescribed fire while attempting to mitigate the negative impacts of smoke through smoke management. Smoke management tools (Southern Forest Fire Laboratory Staff 1976, National Wildfire Coordinating Group 1985) have been designed to avoid violation of the Clean Air Act and its amendments that mandate air quality standards. Neither the standards nor available management tools directly address the effect of forestry smoke on visibility and highway safety. Over the past 15 years, roadway safety problems associated with smoke have been identified as a major obstacle to the continued use of prescribed fire as a forest management tool in the South.

Predicting the impact of smoke on highway visibility is a complex problem. Systems analysis, the study of the behavior of, and interactions among, components in a model of a complex system, provides a useful methodology to address the problem. Initially, the highway visibility problem can be broken into four components: combustion, emissions, dispersion (diffusion), and visibility. The combustion process produces a certain amount of smoke which disperses through the atmosphere, interacting with the background conditions, and resulting in a certain level of visibility. These four components or subsystems can be further subdivided.

There are two aspects of combustion, flaming (associated with the flame front) and smouldering (or glowing). Most, if not all research on fire behavior (e.g., rate of fire spread and fire intensity) has concentrated on flaming combustion. Unfortunately, smouldering combustion makes a major contribution to smoke production. There is a paucity of information on smouldering combustion. Additional research or rules of thumb based on experience must be developed to account for residence time, smouldering combustion, and piled debris burning.

Given information about fuels and combustion, the emission rate can be estimated. Although some research has been done on emissions, there are significant gaps in current knowledge. Given information on the emissions, fire intensity, and weather, the dispersion of smoke can be estimated. A plume model (e.g., Peterson and Lavdas 1986) can be used to estimate smoke concentrations downwind of the source. Models require simplifying assumptions. Given information on dispersion, weather, and the current condition of the atmosphere before the addition of smoke (background), visibility can be estimated.

This cursory analysis of the smoke problem indicates that existing knowledge is incomplete and uncertain. In light of this, what is the best way to manage the forest so that prescribed fires can be used to meet various objectives while minimizing the risk of highway safety problems due to smoke? This paper proposes that there are two essential ingredients to address in the smoke problem, and most other natural resource management problems: 1) a landscape ecology perspective and 2) an adaptive management approach. GIS provides a landscape perspective, while GIS and elements of artificial intelligence (AI), specifically, the construction of knowledge-based systems, provide a means to implement adaptive resource management.

Landscape Ecology
Forman and Godron (1986) state that a landscape is a distinct, measurable unit defined by its recognizable and spatially repetitive cluster of interacting ecosystems, geomorphology, and disturbance regimes. Landscapes may be classified along a gradient, from natural landscapes, to production landscapes such as timber, range, and agricultural landscapes, to urban landscapes. GIS provides a landscape perspective. With the proliferation of GIS software, the landscape viewpoint will become increasingly prominent.

Landscape ecology focuses on three characteristics of the landscape, structure, function, and change. Landscape
ecology studies both the principles concerning structure, function, and change, and their application to the formulation and solving of problems (Forman and Godron 1986).

All landscapes share a common structure of patches (an area differing in appearance from its surroundings), corridors (narrow strips of land which differ from the matrix on either side), and background matrix (a surrounding area that has a different species structure or composition). Many disturbances mold the structure of a landscape. They include natural events such as hurricanes, fires, and pest outbreaks, and human interventions such as plowing, logging, and spraying. Each ecosystem type has a distinctive disturbance regime, that is, the intensities, frequencies, and types of disturbances that occur. In the language of landscape ecology, prescribed fires from patches produce smoke which can drift across corridors, such as highways. Management of the disturbance regime (patch dynamics) requires the use of prescribed fire. Transportation along road corridors should be safe.

Function refers to the flows of energy, mineral nutrients and species, while change refers to the alteration in structure and function over time. Change is the norm in both landscape elements and landscapes. Change implies uncertainty. The single greatest difficulty in managing most landscapes is lack of knowledge of the forces that underlie landscape change (Forman and Godron 1986). A systems analysis approach is often undertaken in an attempt to understand landscape change. Thus, systems analysis and modeling are important parts of landscape management (Forman and Godron 1986). Many types of maps may be used to manage landscapes and it is also possible to build models from these maps. Risk assessment is one of the most useful applications of modeling. Adaptive resource management (modeling the current state of knowledge, making mistakes, and adapting the models to learn from the mistakes) provides an effective means of coping with change and the resulting uncertainty.

Adaptive Resource Management
Adaptive resource management uses the construction of dynamic models as an intellectual device to help people clarify issues, communicate effectively about shared concerns, and explore objectively the consequences of alternative policy options (Holling 1978, Walters 1986). Adaptive policies call for variation and change as essentials to learning. Management is a continual learning process that evolves by learning from mistakes. Yet, it is not simply trial and error. Current knowledge guides future discovery. Actively adaptive, probing, deliberately experimental policies should be a basic part of renewable resource management (Walters 1986).

Designing adaptive management strategies involves:
1) defining and bounding management problems in terms of objectives and constraints,
2) representation of existing understanding so that errors can be detected and used as a basis for further learning,
3) representation of uncertainty and its propagation through time in relation to management actions,
4) design of balanced policies that provide for continuing resource production and protection while simultaneously probing for better understanding and untested opportunity (Walters 1986).

There are formidable obstacles to practical implementation of adaptive resource management. Knowledge-based systems can help overcome those obstacles. Savolainen (1989) explored how a knowledge-based system could represent existing understanding and uncertainty in the design of balanced policy for a wilderness fire management problem. The remainder of this paper focuses on the representation of existing knowledge and the representation of uncertainty in order to balance the need for prescribed fire with the need to minimize the nuisance of smoke. Integrating the various representations can be accomplished with a blackboard.

Representing Existing Knowledge
One of the primary goals of knowledge-based systems is to represent current knowledge. Several methods are used to represent knowledge, among them rules, cases, and models.

Rules
The first knowledge-based systems represented knowledge as rules. Thus, rules have a relatively long history and are firmly entrenched. Even though they have several limitations, rules are currently the most popular and widespread method of representing knowledge. Rules take the familiar form of IF something is true, THEN draw a conclusion or take action (Stock 1987). For example,

If the Keetch-Byram Drought Index (Keetch and Byram 1983) is less than 400, then there will not be much ignition and smoldering of large fuels.

There are already several efforts to link rule-based knowledge systems with GIS. CLIPS has been linked to GRASS by Spectrum Sciences & Software and by researchers at Texas A&M. USGS researchers plan to link Neuron Data’s NEXPERT/OBJECT with ARC/INFO. Coughlan and Running (1989) are also reported to be linking a rule-based system to a GIS. There are probably other efforts too.

Cases
Case-based reasoning (CBR) is used by people or computers to solve new problems by adapting solutions that were used to solve previous problems (Hammond 1989, Kolodner 1988, Riesbeck and Schank 1989). In other words, a case-based reasoner (human or machine) finds those cases in memory that solved problems similar to the current problem, and adapts the previous solution to fit the current problem, taking into account any difference between the current and previous situations.

There are two key issues in CBR: retrieval and adaptation. The most appropriate case to adapt must be retrieved from memory, even when the case may share few superficial features. Adaptation consists of making the right changes to resolve differences between the retrieved case and the current situation.
Prescribed burn plans provide a written record of past prescribed fires. A computerized historical record (case library) of prescribed burns will be developed as part of the smoke management system.

Models

Walters (1986) uses models to represent current knowledge in his formulation of adaptive resource management. The use of models to represent so-called ‘deep knowledge’, as opposed to the ‘surface knowledge’ represented by rules, is receiving increasing attention in AI. Models either have been constructed or are being constructed for the four components (combustion, emissions, dispersion, visibility) of the smoke management system. Dispersion or diffusion models are intrinsically spatial. Smoke drift, fire spread, insect outbreaks, oil spills, etc., are all examples of diffusion processes. GIS should provide a major contribution to dispersion or diffusion modeling.

Models will be used in the smoke management system to the extent we understand the underlying processes of combustion, emissions, dispersion, and visibility. Rules of thumb based on experience will fill in where models are incomplete.

Representing Uncertainty

There are a variety of ways to represent uncertainty (Kanal and Lemmer 1986). How best to represent uncertainty is a hotly debated topic in the AI literature. There are essentially three schools of thought on how to handle uncertainty (Pearl 1988). One approach is to use non-numeric techniques, for example, the development of non-monotonic logics (e.g., McDermott and Doyle 1980, Reiter 1980). Formally, non-monotonic logical systems are logics in which the introduction of new axioms can invalidate old theorems. They come into play when assumptions are made and subsequently revised in light of new observations. A second approach is to make extensive use of probability theory, such as a Bayesian approach. Until recently, one of the major drawbacks to a Bayesian approach was the computational difficulty of arriving at probabilities. Bayesian belief networks (Pearl 1988) are removing many of the computational difficulties. A third approach attempts to overcome the computational complexity by inventing new calculi, for example, fuzzy logic (Zadeh 1965), Dempster-Shafer belief functions (Dempster 1968, Shafer 1976), and certainty factors (Shortliffe and Buchanan 1975). Since certainty factors fit nicely with rules, they are firmly entrenched. Yet, they are probably the weakest form of reasoning about uncertainty.

Each method has strong points and weak points. Walters (1986) used Bayesian methods in his formulation of adaptive resource management. We are looking to incorporate Bayesian methods in the smoke management system because of the strong theoretical foundation, the power of conditional probability statements, and the growing tractability of computations (Lauritzen and Spiegelhalter 1988), and because of the so-called ‘Dutch book’ argument. The Dutch book argument shows that a gambler deviating from the rules of probability calculus will, in the long run, lose against an opponent who adheres to those rules.

Putting It All Together On The Blackboard

Blackboards (Engelmore and Morgan 1988, Hayes-Roth 1985, Nil 1986a, Nil 1986b) provide a means to integrate different representations of knowledge. For example, Rissland and Skalak (1989) combine rule-based and case-based reasoning. In blackboard systems, a problem is decomposed to maximize the independence of the subsystems. This, in turn, provides maximum flexibility in software development. There are three major components to blackboard systems: knowledge sources, blackboard data structure, and a control mechanism. Knowledge sources are separate and independent. Mathematical models, simulation models, relational databases, and GIS can be knowledge sources. Knowledge-based systems that use rules, cases, or models can also be knowledge sources. The blackboard data structure is a global database. Knowledge sources produce changes to the blackboard that lead incrementally to problem solutions. In a pure blackboard system, the control mechanism is such that knowledge sources respond opportunistically to changes in the blackboard. The following analogy further describes a blackboard system.

"Consider a hypothetical problem of a group of people trying to put together a jigsaw puzzle. Imagine a room with a large blackboard and around it a group of people each holding over-size jigsaw pieces. We start with volunteers who put their most 'promising' pieces on the blackboard. Each member of the group looks at his pieces and sees if any of them fit into the pieces already on the blackboard. Those with the appropriate pieces go up to the blackboard and update the evolving solution. The new updates cause other pieces to fall into place, and other people go to the blackboard to add their pieces. The whole puzzle can be solved in complete silence; that is, there need be no direct communication among the group. The apparent cooperative behavior is mediated by the state of the solution on the blackboard. If one watches the task being performed, the solution is built incrementally (one piece at a time) and opportunistically (as an opportunity for adding a piece arises), as opposed to starting say, systematically from the left top corner and trying each piece.

This analogy illustrates quite well the blackboard problem-solving behavior implied in the model. Now let's change the layout of the room in such a way that there is only one center aisle wide enough for one person to get through to the blackboard. Now, no more than one person can go up to the blackboard at one time, and a monitor is needed, someone who can see the group and can choose the order in which a person is to go up to the blackboard. The monitor can ask all people who have pieces to add to raise their hands. The monitor can then choose one person from those with their hands raised. To select one person, some criteria for making the choice is needed. The monitor needs a strategy or a set of strategies for solving the puzzle. The monitor can choose a strategy before the puzzle solving begins or can develop strategies as the solution begins to unfold. In any case, it should be noted that the monitor has
broad executive power. By adding the constraint that solution building physically occur one step at a time in some order determined by the monitor (when multiple steps are possible and desirable), the blackboard model is brought closer to the realities inherent in serial-computing environments. (Nii 1986a).

The final solution for the smoke management system will include a map with the likelihood of various smoke concentrations downwind of the prescribed fire. The blackboard will contain the evolving map as a solution is developed. The need for GIS is obvious. The blackboard will also contain the concept of likelihood, using Bayesian techniques. Knowledge sources will include rules, cases, and models for each of the four components (combustion, emissions, dispersion, visibility).

Summary
The need for prescribed fire in managing forest patch dynamics must be balanced against the need for safe travel along road corridors. Landscape ecology provides the appropriate perspective and emphasizes the important role of change. Adaptive resource management provides an effective means to manage change by requiring the representation of current knowledge and the uncertainty surrounding that knowledge. GIS provides the landscape perspective and tools for developing spatial models. AI, specifically knowledge based systems, provides the tools to represent current knowledge, such as rules, cases, and models. AI also provides a variety of ways to represent uncertainty. Blackboard systems provide a mechanism to integrate AI and GIS to develop adaptive resource management strategies.

References


Natural Language Interface to Geographic Databases. Experiments with Intelligent Assistant

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Abstract
Natural Language Systems (NLS) permit interactions with computer systems in the language and syntax native to the computer operator. These types of interfaces, integrated with complex information systems, could potentially not only raise the efficiency of system use, shorten the training time, and allow for the more precise formulation of queries but also facilitate such system operations as updates, searches, selecting, and generation of reports. Very few publications are available on NLS interfaces to geographic information systems. This paper evaluates the natural language system interface, Intelligent Assistant, to a database containing spatially referenced information in terms of user's input, query formulation, query interpretation by the system and system efficiency. Queries directed to NLS are paralleled on the GIS system to the same database. The comparison between an interface with a command query language and with the NLS interpreter is given. The steps involved in using NLS are explained and demonstrated. Interactive sessions with the system are discussed in detail. Finally, time estimates required for parsing of queries by NLS are provided to allow for the estimation of NLS efficiency.
1.0 Introduction
Effective use of information systems depends largely on the ease with which these systems can be accessed by the user (Petric, 1976, Krausa, 1980). There are several ways in which the access may be simplified. One way is through a natural language interface.

The objective of this paper is to present and evaluate a natural language interface to an information system containing spatially referenced data. The emphasis is on practical aspects of the interaction with a natural language computer front-end. Examples illustrate the process of the lexicon development for the database, the handling of queries with errors, clarification dialogue, and the handling of ellipses. Information on the speed of parsing is given so one may evaluate any extra time required to process natural English commands. References to literature provide some insight into the most recent developments in natural language systems. The authors hope that reading this paper will answer the question “What would a GIS with natural language front-end look like?”

2.0 Natural Language Interfaces
A natural language interface allows the user to interact with the computer system in the user's native language. Using NLS, instead of querying the GIS system with the dialogue:
GIS: RESELECT BASEMAP POLYS LINE = 3
GIS: ARC5 BASEMAP

the user asks:

NLS: SHOW ME ALL THE PRIMARY ROADS ON BASEMAP

(Primary roads have code class = 3)

Several examples of natural language interfaces to information systems can be found in the literature. Hendrix (1977, 1978) discusses the NLS interface, LIFER, to a naval database. Excellent examples of queries of a spatial information database are discussed by Lehnert et al (1980) in her paper on EXPLORER, an NLS front-end for oil exploration systems. Waltz (1978) described PLANES, an NLS interface to an aircraft flight database. More recently, Samad (1986) presented details of CLEOPATRA, an NLS to CAD interface.

2.1 Basic Concepts
An NLS interface, by accepting commands entered in conversational English, allows system use by people without extensive training in computers (Egenhofer et al, 1985).

The advantage of NLS over the system query language is that with NLS the user is exempted from understanding how and what the computer system does. The user may be unfamiliar with the logical structure of the database or with the syntax of the system query language. The user must only know what he wants to retrieve from the system. He does not even have to be correct in typing his request as the NLS interface should be able to handle both imprecise queries and syntactic and spelling errors.

As there is no complete model for the natural, spoken, unbounded language, existing natural language interfaces have been operating on a subset of English, known as restricted English. The question of what is easier to learn, a restricted natural language or an artificial query language, has not yet found a decisive answer (Napier et al, 1989, Samad, 1986). The question of benefits from the use of NLS interfaces is also not clear. Most researchers agree, however, that the problem is not in the concept itself but in the limitations of existing technologies. Krause (1980), Larson (1983), and Napier et al, (1989) indicated some advantages of the use of restricted natural language interfaces with databases or spreadsheets. This research did not answer conclusively for what type of users and applications NLS interfaces are superior to other types of computer-user communication models. Despite all those problems, there is a definite trend to provide, as an option, NLS interfaces to commercial information systems, in particular with DDS or EIS (Larson, 1983, Meador, 1986).

Most NLS described in literature are query and answer systems to non-spatial databases. Few papers can be found on actual examples of NLS to geographic information systems (Bolc, 1984, Kasturi, 1989). Spatial information systems, because of their diverse functionality (Barrera et al, 1981) and complex relationships among database elements would call for much more sophisticated interfaces than those existing ones.

NLS interfaces to spatial information systems may be implemented as the interface to all or some of the system modules. NLS query and answer interfaces to GIS databases would resemble existing natural language interfaces. NLS providing access to GIS modeling capabilities and report and map generation functions would require new capabilities to handle tasks not found in non-spatial databases. An interesting aspect of the use of natural languages in geographic information systems was pointed out by Robinson (1985); he suggested that NLS interfaces may be the best suited tool to handle the fuzziness intrinsic to geographic queries and spatial information.

To sum up, proponents of the use of natural language systems argue that NLS offer the unique flexibility in query formulation, cut down on learning time, do not require translation of problems from 'domain specific' language into a highly-constrained computer query language, and is potentially one language for all the system (Samad, 1986). The opponents of the NLS interfaces, as for example Hill (1983), argue that the inherent ambiguity of natural languages excludes this class of languages from use in analytical tasks. Some argue also that the verbosity of natural language renders NLS ineffective.

3.0 Intelligent Assistant, an NLS Interface to Q&A Database.
Interaction with a geographic database through a natural language system, Intelligent Assistant (IA), will be discussed.
Intelligent Assistant is the natural language interface to Q&A database, an integrated database manager for PC class microcomputers. Using Intelligent Assistant, one can interact with the system using the natural, spoken subset of English. IA allows for record retrieval, the production of tabular reports, mathematical calculations, the creation of new data records and the update of multiple records.

Q&A is not the GIS system. It does not have graphic capabilities nor GIS modeling functions. Q&A is used here as the host of a geographically referenced database and as the shell for a natural language interface. The database implemented in Q&A was extracted from the polygon attribute file of ARC/INFO. To assure the parity of queries on IA with the ARC/INFO query language, the queries on Q&A were paralleled with queries on ARC/PLOT and INFO systems.

The initial step in using the Intelligent Assistant consists of loading IA with information about the database (Edwards, 1986, Hendrix et al 1978). This teaching process must supply the IA dictionary with information on database content, synonyms for items names, adjectives and verbs to be used in queries and synonyms by which the users wishes to query database content.

The query process, using IA, has two phases. In phase one, the system parses the query typed in by the user. The system checks the query against its lexicon and mistakes are flagged out. The user has a choice of correcting the mistake, or, if it was only a word unknown to IA, the user may add this word and its synonyms to the system dictionary. The user may also force the system to come up with its own interpretation of the misspelled, unknown word or the whole phrase. In phase two of the query processing, after parsing, the system provides its interpretation of the request. Here again, the user may accept it or stop the query.

For example, the conversation with IA may look as follows:

**USER INPUT:**
Show me, if th are any polygons with area between 2000 and 5000 and with moisture limitations.

**IA ASKS FOR THE CORRECTION OF “th”**

When corrected to “there” IA provides the interpretation of the query:

**POLYGONS WITH AREA > = 2000 AND <= 5000 AND AGRO-CLIMATE CONTAINS A**

If this interpretation is accepted, the system retrieves information on polygons that satisfy the selection criteria.

### 4.0 Experiments with Intelligent Assistant

The database used in this experiment contains information about Agro-ecological Resource Areas of Alberta and is taken from the work of Pettapeace (1989). The polygon map of agro-ecological resource areas was digitized and set up as a coverage on ARC/INFO. Information related to polygons was encoded in an INFO table and related to the coverage PAT file. Examples of the attribute file which was used in IA queries are given in Table 1. This file contains information on areas of the polygons, polygon ID, names of the regions, names of the agro-ecological resource areas, IDs for the areas, types of landform, types of soil, texture, and agroclimatic limitations for each polygon.

### 4.1 Customizing the NLS Lexicon

IA’s standard lexicon contains some 400 basic words of general applicability (see Table 2). To handle queries to the database, the NLS dictionary must be expanded to include words and expressions specific to the database. This teaching process, known as customizing, is carried out in two steps. In step one, synonyms for item names are coded into the system. In step two, synonyms that describe database content are supplied to the system dictionary. Examples of synonyms for item names are given in Table 3. Synonyms referring to database content are much more difficult to implement, they must express the meaning of sometimes complex coding schemes of items in the database. They must also reflect the language by which the user searches for particular database elements. Problems related to the implementation of the proper subset of expressions are both of technical and lexical nature. On one hand, one must think of the language the user will use to query the database. On the other hand, the system itself is imposing limitations on the length and complexity of admissible synonyms. In the experimental database, it was impossible, therefore, to implement the full phrase:

<table>
<thead>
<tr>
<th>AREA</th>
<th>POLY</th>
<th>REGION</th>
<th>AREA-NAME</th>
<th>LANDFORM</th>
<th>TEXTURE</th>
<th>SOILS</th>
<th>AGRO-CLIMATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>172643.549</td>
<td>2.</td>
<td>Western Uplands, foothills</td>
<td>Mountains</td>
<td>UNLC</td>
<td>UNCL</td>
<td>UNCL</td>
<td>UNCL</td>
</tr>
<tr>
<td>9369.168</td>
<td>3.</td>
<td>Clear Hills - Zama</td>
<td>Zama Lake</td>
<td>L(U)</td>
<td>CL</td>
<td>GL-O</td>
<td>4H</td>
</tr>
<tr>
<td>15725.415</td>
<td>5.</td>
<td>Manning - High Level</td>
<td>High Level</td>
<td>L(U)</td>
<td>SIC-SIL</td>
<td>GL(SO, 0)</td>
<td>3H(4H)</td>
</tr>
<tr>
<td>16540.763</td>
<td>7.</td>
<td>Clear Hills - Zama</td>
<td>Rainbow Lake</td>
<td>U(H)</td>
<td>CL-SIC</td>
<td>GL-SC</td>
<td>4H</td>
</tr>
<tr>
<td>2633.464</td>
<td>8.</td>
<td>Fort Vermilion</td>
<td>Boyer River</td>
<td>U</td>
<td>SL(S)</td>
<td>GL(SO, 0)</td>
<td>2AH</td>
</tr>
<tr>
<td>2034.713</td>
<td>9.</td>
<td>Fort Vermilion</td>
<td>Plante</td>
<td>L(U)</td>
<td>SIH-SIL</td>
<td>GL(DG)</td>
<td>2AH</td>
</tr>
<tr>
<td>2447.619</td>
<td>10.</td>
<td>Clear Hills - Zama</td>
<td>Milligan Hills</td>
<td>H</td>
<td>CL</td>
<td>GL(O)</td>
<td>5H</td>
</tr>
<tr>
<td>6186.777</td>
<td>11.</td>
<td>Clear Hills - Zama</td>
<td>Otter Lake</td>
<td>H-U</td>
<td>CL(SL, C)</td>
<td>GL(O)</td>
<td>4H-5H</td>
</tr>
<tr>
<td>6636.840</td>
<td>12.</td>
<td>Manning - High Level</td>
<td>Manning</td>
<td>L</td>
<td>C-SIC</td>
<td>S0(GL-DG)</td>
<td>3H</td>
</tr>
<tr>
<td>11284.989</td>
<td>13.</td>
<td>Clear Hills - Zama</td>
<td>Clear Hills</td>
<td>H(S)</td>
<td>CL</td>
<td>GL(O)</td>
<td>5H</td>
</tr>
</tbody>
</table>

Table 1. Sample of database implemented on Q&A system.
Hummocky uplands — hill lands — slopes of 5-15%

It was also impossible to implement the synonym:

Hill lands — Hummocky uplands and Hill lands

as the system went to recursive substitution.

Examples of implemented synonyms are given in Table 4. Synonyms determine how someone may query the database. Thus, the selection of synonyms should be done after the user’s ‘language’ is studied. In addition to synonyms for items, synonyms that are related to verbs, adjectives and adverbs used in the queries should be supplied to the system. They make the conversation with NLS look more ‘natural’. Only a few synonyms in this group were implemented in this exercise.

4.2 Queries

To test the effectiveness of the NLS interface and to demonstrate interaction with the GIS database, several queries of the agro-ecological resource areas attribute file were performed. Some of these queries are given in Table 5 and Table 6. Table 6 provides examples of queries in ARC/ PLOT or INFO language parallel to NLS queries. Those queries were directed to the same database located on ARC/INFO.

(1) Where are zones with mainly spteeplands?
(2) Show polygons with severe climatic limitations.
(3) Show polygons with area greater than 3000.
(4) How many areas have slight moisture limitations.
(5) What is their total area.
(6) Where is the largest polygon with severe heat limitations.
(7) Show agro-ecological resource areas with slight moisture limitations.
(8) What is the total area of polygons with slope > 15%.
(9) What is the average size of polygons with slight moisture limitations.
(10) Is there any polygons with area between 2000 and 5000 and moisture limitations with site.
(11) Display region area-name for agro-ecological resource areas with soil and two or more landforms predominantly undulating sorted by area-name and region with heat limitations and with area not greater than 6000.

TABLE 5. Examples of queries of the test database.

4.3 Handling of Errors

NLS response to two types of errors in the queries was evaluated: spelling errors and grammatical errors. The following questions were given:

(a) Show polygon greater than 3000.

and

(b) List polygons in descending order sorted has texture contains Si.
5.0 Conclusions

Natural language-based interfaces offer an interesting alternative to command query languages, object icon-type interfaces, menu-driven systems or form fill-in interfaces (CBE) (Napier, 1989). NLS interfaces seem to be particularly suited to systems where queries are initially formulated in domain-specific, not artificial, language and the potential user of the system is not well trained in formal database design and system use. These features are characteristic of geographic information systems.

Ease of use of an NLS depends on the ability of the NLS engine to handle complex linguistic forms and on the ease with which NLS may be adapted to the particular application. The process of teaching NLS the knowledge necessary to handle user’s input may be discouraging and expensive, especially for dynamic databases.

GIS systems would certainly benefit from having, as an option to menus and a command language, an NLS interface. With a trend toward SQL in GIS systems, implementation of an NLS via SQL may not be too distant. An NLS interface accessing other than query and retrieval functions of GIS systems may require more research into linguistic aspects of GIS dialogue. Research into natural languages may also stimulate the development of algorithms to handle fuzzy requests of the type “near”, “close”, “not too far”, and “in the vicinity”.

Experiments described in this paper demonstrated the steps involved in the use of NLS systems. The NLS systems available now require some preliminary work that may be discouraging. The process of formulating queries using NLS allows for the retrieval of database items (polygons) without knowing how they were coded. In case of the database presented, it was of particular importance, since the coding scheme was quite convoluted. The formulation of complex queries with several conditions or requests for summary reports was much simpler with NLS than with the GIS query language. Using Intelligent Assistant, the polygon attribute file could have been queried by someone without knowledge of how the items were coded or how the system works. The user does not have to know the name of the ‘coverage’ with data, does not have to know what type of coverage it is or what are the names of items he is searching for. The parsing time for queries is quite short so it may be disregarded as a source of problems. Ability to handle

<table>
<thead>
<tr>
<th>Question</th>
<th>Parsing Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show polygons with severe limitations</td>
<td>5</td>
</tr>
<tr>
<td>Show polygons with severe limitations and with area less than 10000.0</td>
<td>7</td>
</tr>
<tr>
<td>List AREA-NAME where area is less than 5000.0</td>
<td>4</td>
</tr>
<tr>
<td>List AREA-NAME where area is less than 5000.0 and more than 2000.0</td>
<td>7</td>
</tr>
<tr>
<td>If there is any polygon with area between 2000 and 5000 and with moisture</td>
<td>10</td>
</tr>
<tr>
<td>limitations with with silt</td>
<td></td>
</tr>
<tr>
<td>Display region area-name for agro-ecological resource areas with silt</td>
<td>24</td>
</tr>
<tr>
<td>and two or more landforms predominantly undulating sorted by area-name and</td>
<td></td>
</tr>
<tr>
<td>region with heat limitations and with area not greater than 10000.0</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 7. Examples of queries and related parsing time.
errors in the input request seems to add a lot of ‘friendliness’ to the system.

The natural language interface presented in this paper did not differ from the NLS supplied to non-spatial databases. Thus, issues specific to GIS such as mentioned fuzziness of GIS queries, an expanded lexicon to handle commands and operations available on GIS systems, access to map generation functions were not reviewed or tested here. The problem of the use of natural language interfaces to computer systems is still open, but may be this paper will stimulate the research in NLS interfaces to geographic information systems.

Acknowledgement
Agro-ecological Resource Areas polygon map in ARC/INFO format was provided by Agriculture Canada, Ottawa. Attribute information for agro-ecological resource areas was input into the system by Agriculture Canada, Edmonton Branch.

References


Appendix 1
Specifications of the PC system on which the Q&A test was carried out.

PC 8088 class machine, DOS 3.3, hard drive 20MB

Norton Computer index (CI) related to IBM/XT 1.0
Norton Disk index (DI) related to IBM/XT 1.7
Norton Performance index (PI) related to IBM/XT 1.2

Data Transfer tor from hard disk 161.3 Kb/sec
Random seek; average access time 61.0 ms
Track-to-track seek; track to track access time 14.1 ms
Automated Labeling System for the Alberta Vegetation Inventory Project

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Abstract
This paper describes an implementation of an automatic label placement system for thematic data. This system was designed for a specific mapping project utilizing both the INTERGRAPH graphic system and ARC/INFO GIS system. Initially, a raster data model is created from several single variable files built through ESRI's ARC/INFO rasterization. The set of all possible label placement locations is defined and searched using heuristics. As the final result, all placeable labels are correctly positioned, either inside the polygons or outside with text leaders added where necessary. Labels for which no locations could be found within known constraints are clearly marked for operators attention.
2.3 Raster Model Analysis
Initially the approximate distance from the constraining borders (map edge, polygon boundary, ATS line) for every grid cell in the raster model is calculated. From a set of cells known to belong to one polygon, the centre, most optimal text location is selected. Each polygon range is also calculated and stored.

2.4 Text Placement Phase
The preferable locations for the labels and possible text leaders are defined through analysis of the raster model. The general approach is to place all labels that fit inside the associated polygons at centre locations to form the starting partial solution. A map of coarse grid cells is superimposed and each cell is analyzed for its local free space areas. Selected points are stored as potential label locations. Figure 5 presents these points for a selected area. For all non-labelled polygons, the list relating polygons with possible location points in grid cells is created. Another list defines density of the possible grid utilization reflected by a number of polygons competing for the label location inside a given cell. Utilizing heuristics and the mentioned lists, the system places as many labels as possible. Its primary rule is to place the label with a smaller degree of freedom before a label with a larger degree of freedom in a grid cell with the
2.5 Text Node Modification

The text node locations, and colour, in the INTERGRAPH graphics file are changed according to information calculated in the text placement phase. Figure 6 illustrates the initial text node locations (internal points manually digitized). The location of the text node for polygon 183 was chosen with an average size label in mind. In fact, it is not a correct location for its label. Also, the polygon 152 text node is not accurately positioned, but for a different reason. The ATS lines are not considered at the time of digitizing, but they limit the available space for labels.

Figure 7 displays the updated text node locations with label information calculated by the Automated Labeling System. A different colour is used to mark nodes/texts that could not be correctly placed automatically and require graphic operator attention.

3. Results and Conclusions

The Automated Labeling System has been operational for several months and has allowed significant savings in manpower and cost in producing the labelled topographic maps. All processes, data transfers and error handling are controlled through ARC/INFO Macro Language (AML) and DCL commands and are executed either on batch processors or interactively. The CPU time requirements are not very significant and, on average, processing of a medium-sized coverage (~500 polygons) takes less than 10 minutes of CPU time on a VAX 785 class minicomputer. The most serious problem that developed in the AVI project was the occurrence of very dense coverages with the number of polygons exceeding 950, and a very complex forest cover. In this case, when placing of labels inside the township borders is physically impossible, the Automated Labeling System identifies a high percentage of unplaceable labels (up to 15%). The Land Information Services Division is currently analyzing the alternatives for labeling such maps and an upgrade to the Labeling System is to be implemented in the near future.

The current system provides a modularized solution that can be used for a wide areas of application through the manipulation of active parameters and software modules. The AVI specific conditions and requirements were used to optimize the functionality, structures and data flow. Different applications might require modifications or additions of some specific or more generalized routines.

The new modules could address the following concerns:

- Text label rotation. Coverages could be rotated before rasterization,
- Accommodation of other placement techniques as integer programming,
- Optimization techniques to define process parameters based on current data and system behaviour. These parameters could be utilized for each subsequent process,
- Name placement for different cartographic features,
- Modifications to user defined input and output requirements as creation of annotation coverages.

References


Special Interest Group

Session G6
Issues in GIS Education

Issues to Consider When Developing or Selecting a GIS Curriculum

A One-year GIS Curriculum for Professional Teaching GIS at the University of Idaho

GIS Education in Developing Countries - A Case Study from Tanzania
Issues to Consider When Developing or Selecting a GIS Curriculum

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Abstract
A number of model curricula have been developed for GIS. The various curricula designs represent different educational philosophies and different approaches to GIS. This presentation will introduce a number of GIS curricula, outlining issues that must be confronted when developing GIS programs. An attempt is made to match GIS curricula with GIS employment expectations. The paper should be of interest to those interested in enrolling in GIS courses, and those confronted with the task of hiring GIS expertise.
1. Introduction
Following two decades of research and development, digital geographical information systems (GIS) have become operational and popularized throughout the 1980s. This popularization has placed increased pressure on universities and colleges to offer introductory and advanced courses covering GIS, as well as digital cartography and geographical information analysis (GIA).

Educational institutions have responded to this pressure in a number of different ways. Some university departments have incorporated GIS by simply changing the content of one or a number of existing courses without actually altering their existing curriculum structure. Other university departments have attempted to build entire new programs to meet demands, including the establishment of teaching laboratories. Some technical colleges have set up GIS training programs, and some institutions have gone so far as to establish interdisciplinary centres and programs specializing in GIS.

The experiences gained from the various attempts to incorporate GIS in teaching curricula have been discussed at a number of conferences and in workshops (Carter, 1985, 1987; Goodchild, 1985; Jenks, 1987; Nyerges and Chrisman, 1989; Parent, 1988 and Poiker, 1985). Last year, following a decade of experimentation, a number of model GIS curricula have been proposed.

Individuals practicing resource management, municipal management, forestry or other careers that require the handling of land related information may be interested in taking a course or degree focusing on computer cartography or GIS, or may be confronted with the task of hiring GIS educated and/or trained people. The objectives of this paper, therefore, are to introduce and discuss a number of existing GIS curricula in order to give the reader a better understanding of educational products offered, and to introduce issues to be considered when making decisions which include educational program evaluation. The goal of the paper, therefore, is to raise awareness concerning issues of GIS education and training amongst those interested in advancing their GIS education, and amongst those contemplating hiring GIS expertise.

The remainder of the paper is structured as follows: To give the reader an opportunity to compare a number of GIS programs, the following section will introduce and discuss three GIS curricula developed. In order for the reader to evaluate the constraints under which a GIS program must operate, the next section will list the operational issues that must be considered when setting up such a program. This is followed by a discussion of GIS curricula in relation to expected GIS expertise.

2. Three GIS Curricula
2.1 Introduction
This section introduces the reader to three GIS curricula. An attempt was made to select curricula from programs reflecting different sizes of institutions and program design philosophies. Curricula selected are the NCGIA core curricula proposed by the United States National Centre for Geographical Information Analysis and the GIS programs offered in the Department of Geography, the University of Washington, Washington and the Department of Geography, the University of Victoria, British Columbia.

2.2 NCGIA Curriculum Proposal
The National Centre for Geographical Information Analysis (NCGIA) some time ago recognized the need for a GIS core curriculum model. In 1988-89, using academic and private sector experts from around the world, NCGIA developed a set of course materials for a one year introductory curriculum in GIS. A draft version of the curriculum content is now complete, and is being tested by departments around the world (NCGIA 1989a,b and c). After a year of evaluation, the curriculum is to be revised over the summer of 1990, with final release scheduled for July 1990.

The philosophy underlying the core curriculum design is the recognition that GIS is still in its early stages of development, and that development to date has been driven by applications rather than theoretical aspects. The curriculum, therefore, has been designed to attempt to balance the needs of the job market and the need to educate and advance GIS users in theories of cartography and spatial analysis. The NCGIA curriculum shows strong ties between GIS and land information analysis (spatial analysis).

The NCGIA GIS course content is designed for instruction at the university upper division undergraduate level. It is a three course curriculum, each course consisting of 25 lectures. Topics covered are shown in Table 1. The first course functions to introduce students to hardware, software and operations of GIS, providing the essentials required by a beginning GIS technician. The remaining two courses are advanced, focusing on technical aspects and applied aspects respectively. The technical course is designed to explore areas related to the computer science and computer cartography roots of GIS. The applied course deals with applications, management, spatial analysis and spatial decision making. The idea underlying the core curriculum is for educators to teach the content in three consecutive courses as suggested by the NCGIA, or to select and integrate into an existing course structure a set of topics from the seventy-five lectures to suit the needs of individual institutions and departments.

2.3 University of Washington Curriculum Proposal
Nyerges and Chrisman (1989) have proposed a framework for a model curriculum in cartography and GIS, termed CAGIS, which was developed during discussions held when reorganizing the University of Washington's cartography program in the Department of Geography. Contrary to the NCGIA core curriculum, which shows close ties to spatial analysis, CAGIS is more closely tied to cartography, emphasizing cartographic principles, computer cartography and programming.

Nyerges and Chrisman note that CAGIS breaks from the traditional approach to curriculum development along a linear sequence of courses aiming at continued knowledge...
<table>
<thead>
<tr>
<th>LECTURE #</th>
<th>TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>INTRODUCTION TO GIS</td>
</tr>
<tr>
<td>1, 2, 3</td>
<td>Introduction</td>
</tr>
<tr>
<td>4, 5, 6</td>
<td>Hardware and Software Overview</td>
</tr>
<tr>
<td>7, 8, 9</td>
<td>Raster Based GIS</td>
</tr>
<tr>
<td>10, 11</td>
<td>Data Acquisition</td>
</tr>
<tr>
<td>12, 13</td>
<td>Nature of Spatial Data</td>
</tr>
<tr>
<td>14, 15</td>
<td>Spatial Objects and Spatial Relationships</td>
</tr>
<tr>
<td>16-22</td>
<td>GIS Functionality</td>
</tr>
<tr>
<td>23, 24</td>
<td>Raster/Vector Contrasts and Issues</td>
</tr>
<tr>
<td>25</td>
<td>Trends in GIS</td>
</tr>
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<table>
<thead>
<tr>
<th>II</th>
<th>TECHNICAL ISSUES IN GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>26-29</td>
<td>Projections and Geocoding</td>
</tr>
<tr>
<td>30-34</td>
<td>Data Structure and Algorithms: Vector</td>
</tr>
<tr>
<td>35-37</td>
<td>Data Structure and Algorithms: Raster</td>
</tr>
<tr>
<td>38-42</td>
<td>Data Structures and Algorithms for Surface, Volumes and Time</td>
</tr>
<tr>
<td>43, 44</td>
<td>Databases for GIS</td>
</tr>
<tr>
<td>45-48</td>
<td>Error Modelling and Uncertainty</td>
</tr>
<tr>
<td>49-50</td>
<td>Visualization</td>
</tr>
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<table>
<thead>
<tr>
<th>III</th>
<th>APPLICATION ISSUES IN GIS</th>
</tr>
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<tbody>
<tr>
<td>51-53</td>
<td>Introduction to Application Areas and Techniques</td>
</tr>
<tr>
<td>54-57</td>
<td>Decision Making in a GIS Context</td>
</tr>
<tr>
<td>58-63</td>
<td>Project Lifecycle</td>
</tr>
<tr>
<td>64-65</td>
<td>The Multipurpose Cadastre</td>
</tr>
<tr>
<td>66-68</td>
<td>Impact of GIS Management Structures, Economics and Institutions</td>
</tr>
<tr>
<td>69, 70</td>
<td>Database Design for GIS</td>
</tr>
<tr>
<td>71, 72</td>
<td>Data Exchange and Standards</td>
</tr>
<tr>
<td>73, 74</td>
<td>New Directions in GIS</td>
</tr>
<tr>
<td>75</td>
<td>Impacts of GIS</td>
</tr>
</tbody>
</table>

Source: Adapted from NCGIA, 1989a, b, c.

Table 1. NCGIA Core Curriculum Course Content

and skill refinement. Instead, their curriculum design is argued to adopt a modular matrix approach to increase flexibility. However, an examination of their curriculum proposal reveals that the concept of a linear course sequence is not lost in the modular matrix, given that an inspection of the modules allows one to identify logical course progression.

CAGIS is based on 11 courses, starting with an introductory second year undergraduate course, and ranging to advanced graduate courses. The course contents are shown in Table 2. A detailed examination and critique of the CAGIS curriculum proposal is beyond the length of this paper. It should suffice to observe here that Nyerges and Chrisman note that course 258 is designed as a general introductory course to GIS and cartography, that courses 360, 460 and 483 are designed to elaborate on concepts and principles while providing the student with some user experience, that courses 485, 563 and 565 are computer programming and system development oriented courses, and that courses 458, 520, 529 and 560 focus on system design and system use.

2.4 University of Victoria Curriculum
The teaching curriculum of the Department of Geography at the University of Victoria allows students to gain a specialization in GIS by taking a set of courses as outlined in Table 3. Pre-requisites to Geog. 428, the course specializing in
<table>
<thead>
<tr>
<th>Topic</th>
<th>Course Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Materials</td>
<td>2 3 4 4 4 4</td>
</tr>
<tr>
<td>Data Collection</td>
<td>5 6 5 6 5 6 6</td>
</tr>
<tr>
<td>Compilation &amp; Integration</td>
<td>8 0 8 0 3 3 5</td>
</tr>
<tr>
<td>Graphic Design Principles</td>
<td>2 3 3 3 3 4 3</td>
</tr>
<tr>
<td>Symbolization</td>
<td>1 2 1 2 2 2 4</td>
</tr>
<tr>
<td>Map Production</td>
<td>1 2 1 2 4 4 2</td>
</tr>
<tr>
<td>Cognition</td>
<td>1 2 3 3 3 3 4</td>
</tr>
<tr>
<td>Projections</td>
<td>1 2 2 2 2 3 3</td>
</tr>
<tr>
<td>Coordinate Systems</td>
<td>1 2 2 2 2 3 3</td>
</tr>
<tr>
<td>Generalization</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Map Typologies</td>
<td>1 2 3 3 3 3 4</td>
</tr>
<tr>
<td>Spatial Reasoning</td>
<td>1 2 3 3 3 3 4</td>
</tr>
<tr>
<td>Processing 0/1/2/3d Data</td>
<td>1 2 3 3 3 3 4</td>
</tr>
<tr>
<td>Error and Consequences</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Data Structures</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Data Models</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Data Base Design</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Implementation in Society</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Algorithms &amp; Programming</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>Knowledge-Based</td>
<td>1 2 1 2 3 3 4</td>
</tr>
<tr>
<td>System Integration</td>
<td>1 2 1 2 3 3 4</td>
</tr>
</tbody>
</table>

1: Exposure to topic  
2: Principles behind topic  
3: Master tools to address topic  
4: Construct own tools for topic

Table 2. University of Washington Matrix of CAGIS Topics and Courses

GIS, are a background in statistical principles, an introductory knowledge of basic cartographic principles, and credits in an introductory mathematics and computer science course.

The courses listed in Table 3 cover the following materials. Geog. 321 introduces students to parametric and non-parametric statistics. Geog. 323 introduces students to map projections, coordinate systems, datum, directionality, spatial data, cartographic generalization, data reduction, map design, colour theory, typography and issues of professional conduct. Students interested in remote sensing as well as GIS are encouraged to take Geog. 322 followed by Geog. 422, an introductory and advanced course in air photo, remote sensing and digital terrain modelling. Geog. 428 is the Department's core GIS course. Students interested in using GIS for management decision making and planning also are strongly encouraged to take Geog. 426, a course in spatial analysis and decision making, as well as other courses in their area of research interest (resource management, urban studies, transportation, hydrology, geology, tourism, etc.). Students with a strong interest in cartography are encouraged to take Geog. 423, which covers contemporary research in cartography. Those with a special research interest in GIS that is of mutual interest to the GIS instructor(s) may also enrol in a special reading course, which is designed to allow the instructor and the student to develop a course content, assignments and evaluations to suit the specific research project.

The Department of Geography also has an active co-op program, and students with a GIS interest who meet the entrance requirements are encouraged to join the co-op, and to seek GIS working experience during their work terms. This option has proven of great benefit to both students and employers.
<table>
<thead>
<tr>
<th>Year</th>
<th>Courses</th>
<th>Co-op</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st or 2nd Year</td>
<td>321 Introductory Statistics</td>
<td>C</td>
</tr>
<tr>
<td>2nd or 3rd Year</td>
<td>323 Introductory Cartography</td>
<td>W</td>
</tr>
<tr>
<td></td>
<td>322 Introduction to Air Photo and Remote Sensing</td>
<td>O</td>
</tr>
<tr>
<td>3rd or 4th Year</td>
<td>423 Contemporary Spatial GIS Remote Special Issues Analysis Sensing Reading Course</td>
<td>E</td>
</tr>
<tr>
<td>Grad. Level</td>
<td>524 Seminar in Spatial GIS Analysis</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td>528 Seminar in Spatial Analysis Course</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>590 Special Reading Course</td>
<td>C</td>
</tr>
</tbody>
</table>

Table 3. University of Victoria GIS Curriculum

At the graduate level, students with an interest in GIS are encouraged to take seminar courses in GIS and spatial decision making, followed by a special reading course with the GIS instructor(s). The special reading course allows the student to assemble, compile and summarize literature of relevance to the student's thesis topic, as well as preparing a pilot project design. There exists an option for graduate co-op, but work term employment should be related directly to the student's research, and should not force the student to bias research conduct or findings.

3. Operational Considerations

3.1 Introduction

It is generally recognized that a company, municipality or government department's entry into the field of GIS is expensive, and that entry involves operational and administrative adjustments. All too often, however, implications of cost and administration are ignored at the outset, leading to potential conflict, bottlenecks and struggle down the road. This holds true, too, for educational institutions. An educational institute wishing to respond to the demand for GIS education and training therefore should confront a number of operational considerations at the outset. Issues to be addressed have been divided below into institutional and infrastructural considerations.

3.2 Institutional Considerations

Institutional considerations should be addressed by both the institution contemplating a GIS curriculum initiative, and the individual, group or department spearheading that initiative. The two groups should reach agreement on a number of issues before proceeding with any initiative implementation.

The issues are as follows:
- Identify the degree of commitment and support, in principle, on both sides to develop a program in GIS,
- Determine the size and scale of the program,
- Allocate necessary authorities and responsibilities, including clear identification of channels of reporting and administrative structure,
- Establish time frames for program development,
- Secure financial commitments,
- Define manpower commitments,
- Identify physical plant commitments,
- Reach agreement on a mechanism for evaluating an individuals' efforts and time spent initiating a GIS program, and agreement on implications to career advancement and financial reward.

Lack of a common vision, and lack of an understanding at the outset with respect to the above listed commitments, costs and reward mechanisms, invites trouble. A number of educational GIS programs have developed, or are being developed, where agreement on the above issues was not reached. This has lead, in many cases, to mistrust, ill feelings, and sometimes failure.

3.3 Infrastructural Considerations

It is conceivable that a course in GIS could be taught without access to a laboratory containing GIS equipment. However, it is highly unlikely that a GIS curriculum will be successful and competitive without access to a teaching laboratory for hands on practice. A number of infrastructural considerations, therefore, should be addressed before committing to a GIS curriculum. These considerations can be
divided into issues of laboratory space and furnishing, hardware, software and humanware. Each is discussed below.

The norm for educational institutes, as is true for most other institutions, appears to be to wage continual battles over access to physical space. One of the first steps, therefore, must be to secure adequate space to house a number of instructional GIS, including input and output peripherals. The logical next step is to secure funds to furnish this facility, including the acquisition of hardware and software. It is of interest to note that surprisingly little has been written to assist faculty in making decisions concerning room design and furniture selection. However, design issues, including ergonomics, light reflectance, dust problems, air conditioning, static, noise, visual appeal, etc., should not be ignored when designing a laboratory.

Two considerations all too often forgotten when deciding on hardware and software for a teaching laboratory concern maintenance costs and the rapid advances in GIS technology. Hardware and software vendors charge varying rates for maintenance and support of their products. The result is that, often, a product that appears cheap to acquire turns out to be so expensive to maintain that service contracts cannot be honoured, leading to costly headaches when equipment malfunctions or software proves to be not user-friendly. Also, one of the realities of GIS is that software and hardware are out-of-date the day they are ordered. Mechanisms must therefore be put in place to ensure that operating budgets allow for periodic replacement of outdated equipment.

The last issue concerns GIS curriculum support staff. Faculty often initiate GIS programs without support staff, managing, maintaining and operating the facility on their own. They subsequently find it difficult to justify to their superiors the need for support staff, given that the lab has been operating without it. At the same time, they have a difficult time justifying why they have been neglecting other duties because of time spent maintaining the facility. Educational institutes, as well as faculty, do not benefit from teaching staff spending large proportions of their day unpacking computers, installing and maintaining software, dusting computer screens and trouble-shooting system failures. Support staff should therefore be agreed upon and hired at the outset.

To conclude, a successful and competitive GIS curriculum will most likely require a teaching laboratory. Faculty expected to set up these laboratories should ensure that they have sufficient commitment and support to set up and maintain such a facility, and that their career advancement is not adversely affected because of time spent setting up such a laboratory. Faculty must also recognize that the size and scale of a teaching laboratory will determine the size and extent of the GIS curriculum it supports. Our experience has shown that a laboratory with ten GIS can barely support two concurrent courses, each with an enrolment ceiling of 20 students, in spite of laboratory opening hours of up to 14 hours a day. A realistic curriculum, therefore, must accommodate constraints of laboratories, faculty and support staff.

4. Discussion

As was noted above, individuals practising resource management, municipal management, forestry or other careers that require the handling of land related information may be interested in taking a degree or course focusing on GIS, or may be confronted with the task of hiring GIS educated and/or trained people. The question that must be confronted is which program to enrol in, or which program to hire from.

Program selection will depend on a number of constraints and variables, some of which will have to do with the actual quality or content of a GIS curriculum offered. Constraints such as geographical proximity (access), registration cost, the time the program is scheduled, and barriers to enrolment enforced by entrance requirements or enrolment ceilings often will override considerations of curriculum content and program reputation. However, this paper will address only the latter.

One of the first questions to pose when evaluating amongst different GIS curricula is to examine the nature of the GIS expertise that is desired. This requires a break-down of GIS literate individuals into distinguishable groups. Marble (1979) notes that there exist two types of GIS expertise, created by two educational program structures, one leading to expertise as a GIS user/analyst, the other leading to expertise as a GIS developer/programmer. Parent (1988) distinguishes between the casual GIS user, the GIS user specialist, the GIS developer and the GIS manager. The National Centre for GIS (1989) identifies three groups, the GIS operators, the GIS managers, and the planner/analyst using GIS. The above suggests that there exists a four fold division as follows:

- **Technician/ operator**,
- **System developers/ programmers**,
- **Analyst/ planner**,
- **Manager/ program coordinator**.

Job descriptions calling for a GIS technician or a GIS operator are best served by individuals who have received technical GIS training through a course offered by a regional college or a software vendor. However, individuals hired should bring along a basic knowledge of cartographic principles offered in an introductory university cartography course. Cartographic principles should include map projections, coordinate systems, generalization, symbolization, colour theory, typography and map design. Digital map products displayed over the last few years suggest that cartographic knowledge has been neglected as a hiring criteria when employing GIS technicians, something that has not helped the reputation of digital cartography.

Job descriptions that require software development or software customizing skills are best served by an individual with a rigorous training in computer sciences and an education in GIS as a secondary specialization. The ideal applicant would be a student with a major in computer sciences and a minor in geography, specializing in cartography and GIS. The applicant should have participated in courses emphasizing data structures, data models, algorithms,
system integration, man-machine interaction and contemporary programming issues including artificial intelligence, knowledge-based programming and parallel processing.

Job descriptions that require an individual to use GIS to analyze land related data, and to conduct spatial planning are best served by an applicant with a rigorous education in spatial analysis, spatial statistics and spatial reasoning, including considerable exposure to courses discussing errors arising from data accuracy, precision and processing as well as error consequences. Potential job candidates should also bring with them a sound knowledge of the appropriate field of application, such as forestry, soil sciences, geology, municipal planning, etc.

Individuals hired to manage or coordinate a GIS facility are required to have an introductory knowledge of all facets of GIS. This includes some experience with the technical skills required for GIS operation. The latter is important since managers, all too often, do not understand the daily problems encountered on the shop floor when entering and routinely processing geographical information, leading to unnecessary misunderstandings and friction. Managers should have participated in GIS courses emphasizing system evaluation, system implementation, system integration and system lifecycle.

5. Summary
This paper has set out to raise awareness concerning issues of GIS education and training amongst those interested in advancing their GIS education, and amongst those contemplating hiring GIS expertise. The paper should have demonstrated that different GIS programs emphasize different aspects of GIS. It should have become clear that some programs focus on technical skills, some emphasize the cartographic roots of GIS, some specialize in the analysis and interpretation of geographical information, some focus on computer programming and system development, while still others emphasize managerial issues. It was argued that GIS programs are constrained by a number of variables, most noticeably the number of faculty available to support the program and the resources available to establish teaching and research laboratories. However, it should be kept in mind that program content ultimately reflects the background and research interests of the faculty teaching the curriculum.

Cartography and spatial analysis, the basic fundamentals of GIS, have their roots in geography. However, the study of GIS, by application, is interdisciplinary in nature. Those involved in GIS therefore frequently will require multidisciplinary training and joint degrees. Individuals with a sound knowledge of an area of application without proper education in GIS are as unsatisfactory and potentially misdirected as are those with a sound education in GIS without the necessary body of knowledge in the application field.

Successful participation in GIS implies the assemblage of a team that has appropriate levels of training and education. Those in charge of hiring must look beyond software and hardware training experience to individuals educated in different aspects of GIS. Without a soundly educated team, Nyerges and Chrisman correctly note that users of computer cartography and GIS will perhaps only make bigger and faster mistakes than ever before.

6. References


NCGIA 1989a. Introductions to GIS. National Centre for Geographical Information Analysis core curriculum series, draft version.


NCGIA 1989c. Applications Issues in GIS. National Centre for Geographical Information Analysis core curriculum series, draft version.


A One-year GIS Curriculum for Professionals

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Abstract
The British Columbia Institute of Technology has begun a comprehensive educational and training plan in Geographic Information Systems (GIS). This plan embraces both full-time and part-time courses of studies, and is aimed at preparing potential users of GIS in government and industry with the tools required to manage and utilize GIS technology effectively. The curriculum, courses, and facilities are described, the first year of full operation is reviewed and evaluated, and revisions and future possibilities are outlined.
Teaching GIS at the University of Idaho

Toru Otawa and Craig Rindlisbacher

Department of Landscape Architecture
College of Art & Architecture
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83843
USA

Abstract

GIS Primer, a university-wide, introductory GIS course, has been offered at the University of Idaho for two years in response to the growing needs for GIS specialists. It is team-taught by instructors from Landscape Architecture and Geography. Multi-disciplines are represented in the student body: Geography, Landscape Architecture, Forestry, Soil Science, Agriculture and others. The course includes lectures, hands-on laboratory exercises, and guest lectures by several GIS experts in natural resource management, and urban and regional planning. Once students complete the GIS Primer, they may enrol in advanced GIS courses in various disciplines. Advanced courses are currently taught in Landscape Architecture and Geography. Hands-on laboratory work uses advanced ARC/INFO GIS software in these courses.
Introduction
In 1987, a multi-disciplinary committee was convened to address the need for an introductory course for GIS at the University of Idaho. The main goal of this committee was to reorganize the GIS related courses on campus and to address the growing needs for a university-wide, introductory course which was aimed at non-technical students from a wide variety of disciplines. Prior to this endeavor, a few GIS-related courses had been taught in various disciplines at the University: in Geography, a course was taught on the University of Idaho IBM mainframe, while in Forestry, a remote sensing course was offered. In Landscape Architecture, a computer-aided regional land planning course was taught using a mini-based GIS. GIS courses had been taught at the senior and graduate levels, therefore the old GIS curricula were addressing only a small group of students interested in the GIS technologies. There was an urgent need to expand the student base and to promulgate the emerging GIS technologies among undergraduate students. Eventually, this committee effort resulted in an upper undergraduate level course which is to teach the basic principles associated with the GIS technologies, as well as, to provide the students with hands-on experience on PC-based GIS software.

This 'GIS Primer' course has been offered for two years, and over-all results are encouraging. The number of students enrolled in the class rose from 20 to 32 this year, and it is expected to grow as more students show interest in the rapidly changing GIS technologies. As anticipated, the student body represents multi-disciplines, for example, Geography, Landscape Architecture, Agriculture, and Forestry; and the current trends indicate more students from additional disciplines will be involved in GIS in the future.

The objective of this paper is to review the progress made during the past two years and address some of the observed issues. Our multi-disciplinary approach to teaching GIS presented unique opportunities, as well as, some interesting problems which we are determined to solve in our future course offerings. It is hoped that cooperation and better coordination among various disciplines in teaching GIS will benefit students and would lead to a better understanding of GIS and its surrounding issues.

Course Content
The course is primarily organized in three segments: lectures, guest lectures, and hands-on laboratory exercises. Approximately 50% of class time is devoted to lectures with topics including geographic referencing systems, data base design, data entry, spatial analysis and modeling, hardware and software trends, and GIS history. The National Center for Geographic Information and Analysis (NCGIA) curriculum was introduced for the first time to the Primer class in 1989; however, for the most part it did not 'fit' to our course sequence and content. This was because there were too many chapters to cover in a semester and the instructors felt that some were inadequate. With much modification and many deletions, the instructors of the class adopted a few relevant chapters from the NCGIA curriculum.

During the past two years, the class hosted 10 individuals from several government agencies and corporations. Our guest lecturers provided our students with the real life pictures of GIS applications, and therefore very invaluable insight into the issues in GIS operations. The organizations represented include U.S. Forest Service, Bureau of Land Reclamation, Idaho Department of Transportation, Washington Department of Natural Resources, County of Spokane, City of Boise, Boise Cascade Corporation, Potlatch Corporation, Dames and Moore, and GGI. We will continue encouraging the cooperation between GIS professionals and the academic world, as it is very important to involve professionals representing multi-disciplines into our educational process, particularly in light of the fact that GIS is a tool which can be used in numerous disciplines.

The laboratory segment uses a hands-on approach by utilizing PC-based GIS software named GIX developed by Professor Otawa as an instructional tool. The hands-on laboratory exercises focus on various GIS concepts such as overlaying, buffering, query, recoding, classifying, etc. Each command in GIX represents a significant concept of GIS. There are approximately 50 major commands, and students are expected to experiment with all of them through a series of assigned exercises. These commands range from digitizing polygons, lines and points, to map and attribute display, and to a variety of geographic data analysis commands typically found in a raster-based GIS on the market. Once this phase is complete, simple suitability modeling techniques are presented. Instructors regularly require a final project where a student selects and defines his/her own problem and attempts to solve it with GIX. This process involves digitizing of map layers, editing, analysis, printing and report production; and generally, it requires approximately 2 to 3 class weeks to complete the project. This strategy has proven to be a very successful teaching method, since it certifies student involvement in the learning process. Traditional lecturing tends to overlook this aspect of teaching, and supplementing it with non-traditional, hands-on exercises tremendously enhances students' educational opportunity since GIS forces students to think. This learning motivation is initiated by the student and is therefore called 'learner centeredness'.

GIX was designed to promote learner centeredness. Because of its simple pull-down menu system, many first-time users find it reasonably easy to operate once the concept for each command is explained in detail. Its error detection mechanism ensures anticipated input from the user, although much has to be improved. Almost any conceivable type of input error can be expected by the first-time user of GIS, and experience has shown it is extremely difficult to detect those potential errors.

GIX is a family of software routines primarily developed for the IBM PC, XT, AT, PS/2 and compatibles running under MS-DOS and, for the most part, is written in the ANSI-standard C language. The PC environment provides educators with effective instructional tools, since there are a number of PCs readily accessible by students and their operation is easily understood. In addition, their prices are
rapidly falling, enabling students to purchase their own PC. The combination of these factors increases their hands-on opportunities, thus helping them learn the concepts inherent in GIS at their own pace.

GIX uses 8-byte, double precision data for both attribute and coordinates, thereby ensuring relatively accurate results in computations. A system with 640K of conventional memory could accommodate a 200 by 200 matrix, while 2MB of EMS memory would allow a matrix of 512 by 512, or larger. Additional EMS memory allows an even larger data matrix. Two data formats are available in Version 1.0, GDF and DBF. The former is unique to GIX and is comparable to individual map layers, for example, soils and vegetation types. Because of the simplicity in data structure, it employs a typical raster or grid-cell format with the double-precision data assigned to each cell as attributes. The latter is introduced to provide dBASE file compatibility. Once all the map layers are digitized for the region of interest, they can be combined or 'packed' to create a DBF file for data analysis. With this capability, very complex queries can be performed on the existing data base using the Boolean operators — AND, OR, and XOR. All of these functions combined make GIX a true GIS equipped with both mapping and relational data base capabilities. Additional descriptions of GIX functionalities can be found in the papers previously published elsewhere.

**Advanced GIS Courses**

Once students gain a good understanding of GIS in the 'GIS Primer' course, they may enrol in advanced GIS courses offered in various disciplines on campus. Two are currently taught: GEOG 460 (Geographic Information Systems) and LARCH 490 (Computer-aided Regional Landscape Planning). The former focuses on the theoretical aspects of GIS, while the latter is more oriented towards applications of GIS to land planning. Both employ one of the state-of-the-art systems, ARC/INFO.

**Observations**

This new course has so far provided our students with great learning opportunities; however, there have been two major issues observed during the past two years. First, GIS Primer is jointly taught by two departments — Geography and Landscape Architecture. These two disciplines have different interests in GIS and differing approaches to teaching. Geography is primarily interested in the theoretical aspects of GIS, while Landscape Architecture is more application oriented, i.e., using GIS as a tool for land planning and management. The former focuses on lecturing as a prime mode of learning, whereas the latter often uses a studio or laboratory. Many lecture topics must be covered from geography's stand point and also much to cover for hands-on instructions from the landscape architectural positions. A 3-credit (semester) course meets three hours per week, i.e., 51 hours per semester. This amount of contact time is not enough to satisfy both discipline's needs in teaching GIS. This may be advised for other GIS curricula such as the one NCGIA will be proposing in the near future. Our course content requires a more narrow focus and priority settings on lecture topics and laboratory exercises.

More discussions should be pursued on the class content of the absolute minimum which should be covered during one semester.

Secondly, there has not been enough equipment to accommodate our students. For example, 32 students were enrolled in GIS Primer during the 1989 Autumn Semester. Our laboratory is currently equipped with 10 IBM-PC ATs which are shared by 300 other students. Although the laboratory is open from 8:30 a.m. to 11:00 p.m. 7 days a week, accessibility to these systems was quite limited. If a GIS course is to address a wide range of disciplines and students, their access to GIS hardware should be easily available and should not be hindered by the lack of equipment.

**Conclusion**

Our inter-disciplinary approach to teaching GIS has presented a great potential, as well as some problems. Overall, our students benefitted from the diversity of the instructors' backgrounds. With the additional efforts in solving the above-mentioned problems, the GIS Primer course will further improve. As stated, our current curriculum should be modified or fine tuned to fit into the over-all instructional context at the University of Idaho. The proposed NCGIA curriculum will still be a model and will require much modification for adaptation to the University of Idaho curriculum. Additionally, more personal systems are needed to accommodate the heavy demand from our students. The hands-on exercises should be an integral part of GIS courses and therefore these systems are the basic necessity for instructions.

The GIX Primer course provides the students with the fundamental knowledge and skills necessary to apply GIS to various problem-solving. If a student wishes to acquire advanced knowledge and training in GIS, the University offers advanced GIS courses as electives. It is expected that the two-tier approach to teaching GIS will prepare our graduating students with a sufficient base for their prospective GIS-related positions.

**References**


GIS Education in Developing Countries - A Tanzanian Example

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Abstract
There are problems with the successful application of GIS in the management of forests in developing countries, not the least of which is the shortage of adequately trained personnel. This paper considers these problems with special emphasis on the case of Tanzania.