VISUALIZING GEOGRAPHY: USING A GIS TO TURN SPATIAL CONCEPTS INTO REALITY

Lawrie E. Jordan, III, and Stephen L. Sperry
ERDAS, Inc.
2801 Buford Highway NE, Suite 300
Atlanta, Georgia 30329-2137 USA
404/248-9000
Fax: 404/248-9400

COMMISSION IV

ABSTRACT

In the past, the development of GIS software functions has concentrated on replicating manual mapping and analysis procedures. More complex analysis functions have been limited largely by the incompatibility of data formats. Recent GIS software developments have allowed users to access both raster and vector data at the same time. This began a trend toward true data merging. Now users can visualize geography rather than computer files, and much more easily realize solutions to complex spatial problems. This paper will discuss recent trends in geoprocessing and describe software functions, user interfaces and applications which point GIS in the direction of a true geography visualization and analysis tool.

INTRODUCTION

The concept of visualization has its roots in the GIS of the 1970's when manual techniques were used to ingest various data sources into a digital environment. Analysts could use mylar drawn grids to interpret soils information or to capture data from a USGS quadrangle map, aerial photograph, or other source and produce a black and white, or gray-scale, computer generated map. Rather sophisticated analytical techniques were accomplished in the absence of the technology to augment those analyses.

In the late 1970's and early 1980's advances in hardware and software eliminated the need for hand drawn overlays. Digital image processing systems could display and manipulate data. These systems allowed users to classify digital satellite data and aerial photographs into distinct vegetation and landcover classes. These new data layers could be digitally overlaid to show new areas that met several criteria. All visualization was still in two dimensions.

It has been only recently that true three-dimensional analyses have been possible. Through improved hardware and sophisticated software, users can take a drive through the landscape without ever leaving the office. Digital data can be modeled to answer any number of "what if..." questions. Modeling was done in the early days, but steps were recorded in a notebook. Now steps are selected through user-friendly graphical user interfaces and the solutions displayed almost instantaneously on the computer screen. As parameters change, the model can be updated and re-run immediately. An analysis that took weeks to perform in the 1970's now takes just a few minutes; and a three-dimensional view of that analysis can be generated quickly and easily.

The concept of motion and animation in the GIS environment is also relatively new. However, the applications for them are expanding. As GIS is applied toward global research, models are created for weather patterns, carbon dioxide emissions and other global trends. The ability to see the changes in the earth in an animated sequence of images provides scientists and decision makers with undisputed evidence that the future of the planet is in danger. The real power of GIS is in prediction models. Based on past and current data, models can be developed to show how the environment will change if current conditions persist, or if these conditions worsen, and how this future might be altered if preventative measures are enacted. It is one thing to speculate on the effects of global warming, population increases, deforestation and other global problems, it is quite another to see the effects of these situations graphically on an interactive display. A dramatic image can speak much louder than columns of statistics.

CHANGING THE DEFINITION OF GIS

Before GIS can be used for true geographic visualization, the concept of the traditional GIS must be broadened to include all data types-raster, vector, attribute, spreadsheet, ancillary, etc. To derive solutions to the complex problems users bring to GIS requires all available information. Most users now recognize the value of integrating raster and vector data into a GIS. The timeliness and accuracy of satellite imagery and aerial photographs makes data base updates easier and more cost-effective than creating new vector data from ground truth information. The image processing functions available with raster data provide a new level of analysis that adds depth to a GIS. Images can be classified to show wildlife habitats, soils information, vegetative health and numerous other categories that add to the completeness of a GIS.

AVHRR Data

The increased use of Advanced High Resolution Radiometer (AVHRR) data from the National Oceanic and Atmospheric Administration (NOAA) satellites is making global studies easier. The extensive coverage of these data give a picture of an entire continent at one time. Data sets from several years can be used to study change in overall vegetation and land use over time. These multitemporal techniques have been used extensively in South America to track deforestation.

AVHRR data are also being widely used by the United Nations Environment Programme's (UNEP) Global Resource Information Database (GRID). GRID was developed to bridge the gap between the scientific understanding of earth processes and sound management of the environment at national, regional and global levels. GRID provides GIS data layers to users all over the world. These layers cover both regional and global information on political boundaries, elevation, soils, vegetation, watersheds, rainfall, surface temperature, ozone distribution, population density and much more. These data sets are compiled by inputting AVHRR and other satellite data into a GIS. Although GRID users can access all available data sets, they are encouraged to supply UNEP with other data sets in exchange for utilizing the data already in stock. This approach to sharing data helps keep data cost down for everyone and speeds processing. Data acquisition can be a very time consuming and expensive task and often an analysis requires immediate action.

Terrain Data

Besides satellite data and aerial photos, 3D terrain visualization requires elevation data. Digital elevation models (DEMs) have been segregated into a category of their own in the past, but more and more users are realizing the benefits of incorporating terrain data into a GIS. The products you can create from DEMs add a new level of meaning to any analysis.

Some of the layers you can create using elevation data include slope, slope aspect, shaded relief, contour and perspective views. These topographic data are essential for studies of trafficability, route design, non-point source pollution, intervisibility, siting of recreation areas and more. Terrain data can also be used in models and in classification routines. They can, for example, be a key to identifying wildlife habitats that are associated with specific elevations. Slope and aspect maps are often an important factor in assessing the suitability of a site for a proposed use.

DEMs can be purchased from the U.S. Geological Survey (Reston, VA) at 1:250,000 scale for most areas of the United States and at 1:24,000 scale for some areas. DEMs can also be created through traditional photogrammetric triangulation techniques or they can be created in the GIS environment with softcopy photogrammetry software. Softcopy photogrammetry eliminates the need for expensive and complicated instrumentation. This means that elevation data can be created for virtually any study area.

The ERDAS Digital Ortho module (ERDAS, Inc., Atlanta, GA) is an example of a softcopy photogrammetry system. Based on a user-friendly menu and prompt structure, the software carries the user through the process of generating DEMs. These DEMs can be created from overlapping aerial photographs or from SPOT satellite stereopairs. Using information that comes with the aerial photographs or in the SPOT header file and user-selected ground control points, the coordinates of the DEM are calculated through photogrammetric triangulation. Then interactive matching and densification processes are used to calculate the output DEM surface at a user-specified resolution.

By draping aerial photos, satellite images or a GIS analysis onto a DEM, users can create a three-dimensional perspective view. Based on the position from which the view is calculated, the graphic can look like the viewer is standing in or hovering above the landscape. Perspective views are extremely effective in showing before and after scenarios simulating the effect of proposed development or possible land use changes. When several 3D views are combined, they can simulate travel through a landscape.

MEETING USER REQUIREMENTS

As hardware has evolved to handle larger and more complex data sets, so have software packages. GIS has become one of the most rapidly growing segments in the computer industry. Once dominated by a few companies such as Environmental Systems Research Institute, Inc., (ESRI) and ERDAS, Inc., there are now a proliferation of software packages on the market. As GIS applications broaden, products must be designed to be flexible. Along with appropriate functionality, these packages must be easy to use. Today's GIS analyst may be an expert in real estate, insurance or civil engineering, but not necessarily an expert in GIS.

Users have particular problems that must be attacked from specific points of view. Their findings must be presented in a way that both analysts and policy makers can understand. The old cliche that a picture is worth a thousand words seems perfect for GIS. If a static picture is worth a thousand words, how many words is a 3D perspective view worth? What about a 3D view that can be changed as parameters change? Users must be able to query data in three dimensions by geographic region or by a particular theme. "Show me all possible sites where there are both Oak and Pine trees with a body of water not more than 300 meters away and with an elevation of at least 2000 feet that are visible from the proposed parkway." Visual impact is no longer a guessing game. It is now possible to see exactly what the new parkway will look like and what the passengers driving along the parkway will see.

These same techniques were applied in Operation Desert Shield and Desert Storm. Dedicated military and civilian men and women used a GIS to produce some unique map products under very adverse conditions. The success of these endeavors has created a renewed interest in satellite imagery in other military applications such as Mission Planning and Special Operations/low intensity conflict. Satellite images and aerial photographs are invaluable in providing analysts with a current and accurate view of the terrain, creating base maps were none existed. These images can be input into a GIS to model possible effects of proposed actions before any steps are taken.

The Graphical User Interface

The emergence of the graphical user interface (GUI) has shortened the learning curve tremendously. Users do not have to learn a series of commands, or the order in which programs must be run. They can simply point and click. The first ERDAS software package was progressive in its use of a menu-driven set of image processing and GIS programs. Each program contained prompts with intelligent defaults to help guide both experienced and novice users. This environment was carried through the Version 7.5 software package and is still being used by thousands worldwide. However, the newest release, ERDAS IMAGINE, is based on the X Windows GUI. Now processes can be accomplished in any order and at any pace.

Other companies are also embracing the GUI. With the popularity of GUI-based word processing and spreadsheet packages, users are demanding the same ease of use from GIS manufacturers. And since there are certain de facto standards in GUI development, users can easily move from one package to another.

Software Functionality

Beyond the user interface, users are demanding more functionality. The applications of GIS, both locally and globally, are requiring that vendors cater to a much larger audience. A regional planner in California may use GIS to plan new subdivisions and a natural resource analyst in Norway may use GIS to study the effects of global warming on local vegetation, but both of these users require similar tools. The order in which they use the tools is how the two analysts differ. This is where the flexibility of a software package is tested. Analysts all over the world must be able to tailor the software to their particular niche. The sequence in which they each use these same tools must be saved so that others in the field can benefit from their research. In some cases, as with petroleum exploration companies, these steps are proprietary information. But, as with the data sharing concept used by GRID, software solutions can save valuable research time. ERDAS IMAGINE is designed so that scripts can be written for a particular application such as forestry, urban planning, mineral exploration or resource management. These scripts will be written by experts in the respective fields and will contain the common steps used to derive useful end products. Custom dialog boxes and buttons can be designed to provide access to these new scripts. With the effects of global change still under debate, the faster the information is available, the faster solutions can be proposed and legislation implemented.

Since the GIS userbase is expanding so rapidly, it is not feasible to expect vendors to have software particular to every application. Software packages must include a way for users to incorporate their own functions with a toolkit. The ERDAS Software Toolkit, developed under the Version 7 series, enabled users to write new application programs to solve problems specific to their discipline. Some of these programs were later incorporated into the standard ERDAS package. ERDAS continues to encourage user interaction with IMAGINE. Along with the ERDAS Macro Language Script Builder for customizing the interface and grouping processes, the C Programmer's Toolkit allows users to write entirely new functions.

PLANNING FOR THE FUTURE

The continued success of GIS depends on open communication lines between vendors, users and data suppliers. Users have a responsibility to let vendors know what functions they need and vendors have a responsibility to meet those needs in a timely fashion and at prices that are within reach. Data suppliers are obligated to provide accurate and complete data sets that are compatible with other GIS layers. To save time and energy, data and software standards need to be set.

Data Standards

With the growth of GIS and the expansion of application areas there is a need for more types of data. Previously, 16-bit unsigned integer data were the standard. Now, 32-bit signed and unsigned integer data with real and complex values are available. This allows greater dynamic range and precision of analysis. ERDAS has anticipated the growing need for increased precision and has provided 32-bit file capability in ERDAS IMAGINE. Satellite imagery, raster and vector data, demographic information, spreadsheet data, and many other data types that currently exist or are being developed, need to be integrated on a single system quickly and easily.

If many data types are required for a study, how easy, or how difficult, is it going to be to incorporate them into one system? Many software vendors have several conversion routines for the most popular data types such as ARC/INFO, AutoCAD, DLG, ERDAS, SIF, SPANS and a host of other data formats. As more GIS companies are formed and more data formats are developed, the job of writing conversion routines will become enormous. Vendors, users and government organizations must work together. If valuable time is spent on transferring data from one system to another, there is less time for the actual analysis.

Perhaps a single conversion standard would eliminate the need for numerous conversion programs. The U.S. Geological Survey is developing a Spatial Data Transfer Standard (SDTS) to help curb the need for each software vendor to write data transfer routines for each data type they want to import or export. SDTS has been submitted for approval to the National Institute of Standards and Technology. If approved and implemented, SDTS will facilitate the transfer of all GIS data-raster, vector, attribute and ancillary data. It will ensure data integrity by recording and transferring the data's lineage, positional accuracy, attribute accuracy, logical consistency and completeness. The proposed standard also addresses the user's need to transfer data on many types of media, and to add new types of spatial data in the future.

There is also the issue of standards and benchmarks for processing speed and GIS components. Fair and accurate measures of GIS software must be developed to make GIS technology accessible and understandable to the increasing number of generalist users. With equitable standards, it would be possible to confidently shop for the best GIS for a particular application.

CONCLUSION

The technology already exists for true geographic visualization. But technology is not enough. Users must be able to access this technology in real-world situations. They must have hardware and software that is easy to use and that provides solutions to the problems they face. They must be able to interact with the system and to update their information as time, conditions and parameters change. These are exciting times to be involved in the GIS industry. The applications for this very visual science and art is expanding almost daily. GIS has the potential to help solve some extremely crucial and earth-threatening problems: global warming, deforestation, erosion, housing shortages-this list goes on and on. Users, vendors and government agencies must communicate with each other and go forward together to create the map of the future.