Beyond GIS/GPS: Trends in Spatial Data Handling

BY ANDREW ZOLNAI AND MICHAEL MARCHAND

Although some areas are better attuned to 3-D visualization due to the subject matter, GIS is bound to move in that direction rapidly with evolving technologies in true 3-D databases and 3-D graphic workstations. These are exciting times with raster, vector and tabular data merged and distributed over heterogeneous networks. Experience in the private and public resources sector [Crain et al., 19911 suggests the following ideal scenario: A corporate relational database resides on a server, while workstations store client spatial project databases; the server's relational database management system (RDBMS) provides the standards and flexibility to maintain databases of various sources, while workstation project data benefit from the speed of object-oriented spatial indexing. Key issues include data integrity, access and delivery, processing speed, setup cost and maintenance. Paramount to these technical issues is the consideration of individual, work group and corporate "work style." In a trend of collapsing hierarchies, engineers may not have access to technicians, and managers may have to draw their own conclusions on their own desktop systems.

Where is this profusion of solutions leading us in these days of phenomenally increased availability of data, software and hardware? Command-and-control and decision-support systems extend beyond classical GIS applications and serve to illustrate new directions in GIS and global positioning system (GPS] technologies. Both systems benefit from tremendous advances in object-oriented systems and graphic workstations. A person can now point-and-click through spatial what-ifs or monitor assets worldwide at a desktop workstation costing less than $10,000.

A key advantage of object databases is the ability to interact with cartographic elements. Such object queries allow users to zoom into geographic areas ad-infinitum and by-pass the problem of scaling vs. display, thereby abating the longstanding bane of cartographers of which items to show at what scale.

Command and Control

Worldwide cultural databases are available, and the right database engine will show interactively coastline features down to 30-meter resolution on a spheroid projection. This is only the beginning. To develop "fly-by" realistic renderings of critical locations, one can overlay T. Van Sant's global surface imagery (Van Sant, 1989],- drape it over available digital elevation models (DEMs); add reflections, mottling and clouds; and load the information into a graphic workstation. Such renderings offer real-time visualization for emergency planning, search and rescue or command and control.

Better still, one can derive DEMs from SPOT or, soon, ERS-1 images to obtain a sound map base for planning pipeline routing or tracking air, land or sea vehicles anywhere in the world. For example, radio and line-of-sight intervisibility calculations using terrain models help to predict in real-time whether a signal will reach its intended recipient in VHF/UHF or what search-and-rescue plane is able to see units with its sensors over a given flight path.

Interactivity is again paramount to the whole process. For example, Axion Spatial Imaging, a firm in Edmonton, Alberta, Canada, designs Tcrraxion, an integrated system for vehicle tracking, mission control, and search and rescue (Figure 1). A land, sea or air vehicle is monitored against a DEM on a home base graphic workstation with dynamic route corridors.

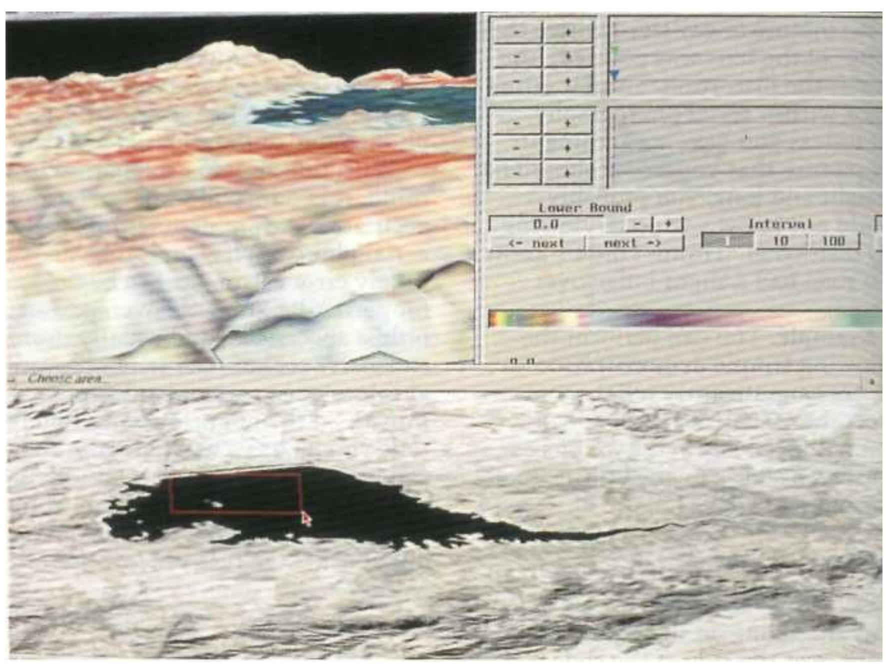

Figure 1. Terraxion's terrain editor with satellite texture mapping, running on a Silicon Graphics Iris Indigo workstation, allows images to be tilted, stretched and filtered to highlight desired features and angles. The product also performs intervisibiiity mapping interactively.

A tanker leaving its shipping lane, for example, trips an alarm signal at home base, and the region is scanned on the workstation to assess whether the ship may have run aground or if piracy is suspected. Search and rescue and law enforcement can be dispatched within minutes of the incident with immensely improved intelligence on existing hazards. Thus, hundreds of vehicles can be tracked simultaneously worldwide on a Silicon Graphics (his Indigo or better) 3-D workstation or 80386/'486 PCs for small fleets.

Decision Support Systems

The ability to link data with maps is nothing new, but adding financials to perform interactive profit-and-loss what-ifs strikes at the heart of any business venture. Imagine being able to extend a road on a vector map overlaid on a raster image filtered to highlight slopes and to interactively create pie charts of the economics of a logging operation. These applications can be performed by using a function that calculates road-building costs vs. logging accessibility and revenues. Facet, a decision-support system supported and marketed by Facet Decision Systems, Calgary, Alberta, and Vancouver, British Columbia, Canada, allows such operations by linking objects in a spreadsheet-like front end, where each cell-object can be another "spreadsheet,'[7] a vector map and/or a raster image (Figure 2).

Using Facet, the profit-and-loss exercise would consist briefly of cells calculating the financial operations, where items are formulas, input data or values automatically derived from linked maps and/or images. Originally developed by MacDonald Dettwiler, Richmond, British Columbia, the software resides on a Sun SPARC station and uses object-oriented data management to link such disparate elements. The product is meant to be the binding agent among many data sources and facilitate the decision-making process by bringing to the desktop relevant data in an intuitively driven, yet powerful, fashion.

Object Databases and 3-D Workstations

The commonality in Axion's vehicle tracking system and Facet's decision-support system are the new database tools and affordable hardware platforms that allow interactive heterogeneous data manipulation in 3-D. These advancements represent outgrowths of existing technologies. From enterprise wide GIS to individual workstations, he they windows into corporate data or standalone projects, a continuous array of applications is emerging in the industry. User-driven demand is creating ingenious new software programs, and a continued drop in hardware prices is bringing all this to today's desktops.

A key element is the ability to create project subsets of corporate data, as well as subsets of subsets, and so on. "Classical" relational databases and structured query language (SQL) standards do not allow imbricate data sets (akin to Russian papier-mache dolls-within-dolls|. Moreover, the speed of relational technology makes it better suited to handle corporate tabular data on a server rather than to process spatially indexed data. Object datahases may best address the latter with XYZ coordinates and attributes embedded in the objects. These components also allow fast graphical display and spatial indexing on a project basis. They do not, as yet, offer data standards to facilitate cross-database information exchange, as has been done in the relational realm. This situation is changing with the object-based SAIF data standard adopted by the Canadian General Standards Board Committee, rather than tables as, for example, SDTS of the U.S. National Institute of Standards and Technology, or DIGEST of the International Digital Geographic Working Group. It is critical to establish standards or put data "loaders" (to reformat and filter data) in the public domain with the explosion of publicly available databases from "canned" applications such as the Digital Chart of the World from Environmental Systems Research Institute and the U.S. Defense Mapping Agency, to "semirefined" data such as Digital Line Graphs from the U.S. Geological Survey, to "raw" data from various federal agencies.

The partition of tasks proposed earlier in this article addresses the dichotomy of RDBMS server and client project spatial datahases. Notwithstanding enormous existing investments in software and hardware, is there a way to seamlessly integrate the two aspects of server and client into one? At first glance, Axion offers end-user applications a 3-D graphic workstation performing command and control. Taken one step further, the vehicles that are the object of tracking, as well as a variety of other pertinent data, could be resident in database servers rather than client project spatial databases.

Facet proposes to "glue" such applications together, manage call-out tasks (such as preparing databases for client applications), and bring pertinent data and analytical power to the manager's desktop. The client-server model, with a remote client such as an aircraft linked by satellite to

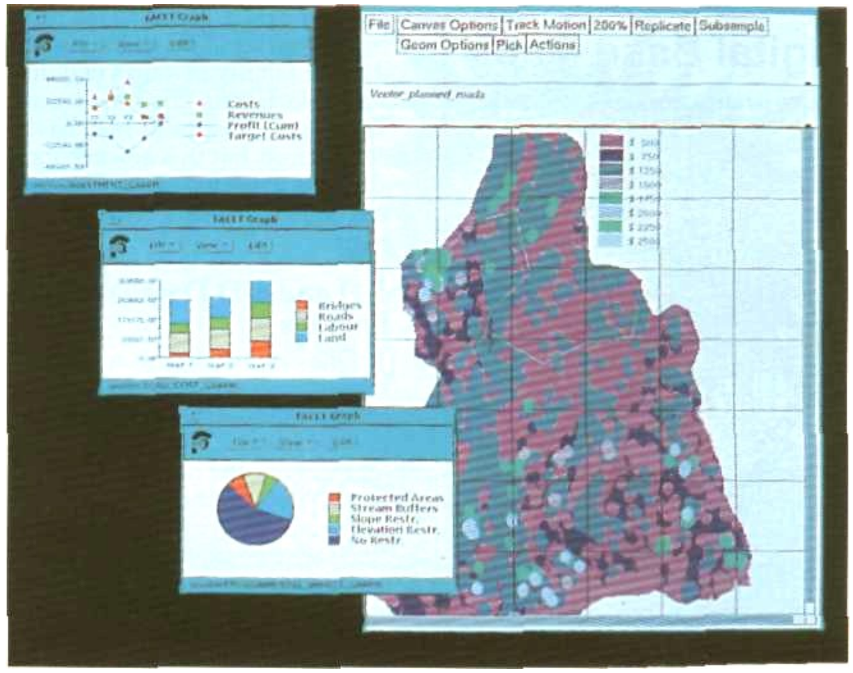

Figure 2. Facet offers slope analysis with vector road maps, bar charts and pie charts linked for cost analysis on Sun SPARC workstations.

monitor a fleet, can have the decision-support server at home base analyze the profitability of routes or quickly assemble data for crisis management. These individual tasks may have been done before, but this new technology allows it to be done interactively in real-time in mission-critical applications.

3-D and 4-D Database Engines

One can map future applications beyond the two examples used. Object databases will mature into true 3-D database engines. Seismic tomography and holograms of the Loma Prieta earthquake epicenters in California two years ago (Harmaway, 1991) are two examples of what 3-D visualization can do. If attribute tables are properly indexed in 3-D, a true 3-D GIS ensues. For example, the performance of a refinery or nuclear reactor can be monitored in 4-D (3-D and real-time attributes are parameters from facilities!, or the evolution of reservoir depletion or contaminant dispersal underground can be mapped (the latter includes probabilistic and geostatistical attributes, which are best-guess distributions of rock and fluid properties in the subsurface]. Real time adds tremendous "dimension" to emergency response in environmental disasters.

What does a 3-D/4-D database entail that does not exist already? Here is a wish list of perceived needs to move database engines into the future; it is hoped that individuals will add their own in a swell of uses for true 3-D GIS (Raper, 1989).

1.The third dimension will not be part of attributes, but a key at the same level as X and Y, and attributes will be properly indexed in 3-D; time need not, as that would require parallelization.

2.Attribute tables will be embedded in 3-D objects, so 3-D computations can be performed on them, for example, not to violate spatial adjacency constraints or allow data spatial filtering.

3.Graphic user interfaces will be developed into "human interfaces" to reduce the disconnectedness the user feels to the simulated environ ment he or she is travelling through. Dynamic Visualization Systems (Tipper, 1991) will enhance the linkage between GIS/RDBMS and application programs.

4.Object data will be normalized to facilitate data exchange between processes and databases. Perfor mance and reliability of systems and data integrity will rely on this. Object databases will not reach critical mass oi acceptance until then, and loaders will need to be in the public domain.

5.Graphics libraries will be standard ized to distribute such applications seamlessly across heterogeneous networks. UNIX is settling into standardization, and graphics appli cations also must mature.

Continued Evolution

The number and variety of options that address spatial data handling are increasing daily. Environmental impact assessment is the fastest growing field in North America, and the booming of public 3-D data sets, for example, from NASA (Strand, 1992), may contribute to pushing GIS from 2-D attributes and DEMs to true 3-D databases. Simulations now can be realistic enough to push the enve lope of "virtual reality" into real-world applications, and handle data sets in 3-D, 4-D and beyond. §

Andrew Zolnai is Calgary AB manager for Axion Spatial Imaging Ltd. Michael Marchand is vice president, product research in Calgary AB for Facet Decision Systems. Both can be reached at PO Box 61121, Kensington Postal Outlet, Calgary AB, Canada, T2N 4S6.

References

Crain, I., M. Marchand and M. Legasse, Eds. 1991. **GIS and Energy,** *URISA 1991 Conference Proceedings.*

Harmaway, W. 1991. **California -the Earthquake, the Hologram.** ***Best*** *Shots - Winning Images from the Second International Visual Computing Awards Contest,* Iris Universe, **No. 18.**

Raper,J., Ed. 1989. *Three-Dimensional Applications in Geographic Information Systems,* Taylor & Francis.

Strand, E.J. 1992. **NASA's EOS Program Marks New Era in Global Change Research,** ***GIS*** *WORLD,* Vol. 5, No. 2 (March 1992).

Tipper, J.C. 1991. **A Prototype General-Purpose Dynamic Visualization System,** *Geobyte,* Vol. *6,* No. 3 (June 1991).

Van Sant, T. 1989. *Geosphere Project,* Santa Monica, Calif.