LEVERAGING VISUALIZATION TECHNOLOGY IN GEOSPATIAL APPLICATIONS

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Abstract
As visualization software technology combined with geospatial components increases in the utility, telecommunications and related industries, applications are providing insight necessary to improving the optimization of network performance, capacity planning and utility asset management. By leveraging advanced visualization technology, complex data is transformed into useful and interactive information, helping to discover new relationships and make better decisions. This paper discusses how to take advantage of using visualization technology in geospatial applications.

Introduction
As distinct technologies, geographic information systems (including geospatial data models), and visualization systems offer complimentary services and data management in application design. By combining them both into an application architecture, full feature sets and benefits of both approaches are realized. This paper introduces the relationship and differences between geospatial models and visualization technology. A series of short case studies present fully developed application scenarios where both geospatial and visualization technologies are well integrated. The case studies cover applications by an Electric Utility Company, three European Telecommunications Companies, and a North American Defense Contractor. As further discussion on how the technologies interact at a technical level, the paper discusses an interface between the Oracle Spatial Cartidge (multi-dimensional spatial database system) and the AVS/Express visualization software system. To conclude, the paper discusses rapid prototyping methodologies for integrating geospatial and visualization software subsystems.

Relationship of Geospatial and Visualization Technologies
It is important at the outset to define a frame of reference for geospatial and visualization technologies before we can discuss how they are integrated and used within an application. In traditional GIS applications, data is held in flat or proprietary structured storage systems. The data held in GIS repositories consists of three main types: raster or gridded data, vector elements for positional, shape, or coverage data, and multi-variate attribute data associated with geographically located positions. GIS applications typically process a large number of logical layers for a given area, often including data sources at different resolutions or scales. The display and review of GIS data is typically through direct graphics display to the window system, showing a subset of available 2D layers. The third dimension, when used, is generated by assigning an attribute such as elevation to create a 3D surface display.

The area of visualization technology focuses on the issues of processing a wide variety of data sources for interactive graphics display. Data models used for visualization are both spatial coordinate based, and non-spatial abstract data model based. The data models in visualization systems are generalized and abstracted for use in a wide range of fields. Visualization systems include many methods for creating abstract visualization objects suitable for graphics display. These are abstract representations of data, rather than direct display of data. This abstraction layer allows processing during visualization, such as contouring, interpolation, feature identification, and sampling from continuous fields [Wiss 98].

The abstract visualization object approach allows "Closed Loop" interaction. Rather than viewing visualization as a one-way process, direct mouse interaction with the graphics is what is used to drive further processing or changes of parameters of the data processing. The concept of using the visualization itself as the interactive user interface of the application is called "Visual User Interface" (VUI). It enables much more intuitive exploration of data than using secondary menu systems to steer the graphics display [Jern 99, Brown 95].

When geospatial and visualization systems are coupled together, each perform in areas where they are best designed. The geospatial operators manage data access, navigation, coordinate systems, and spatial analysis. The visualization system creates a rich graphics environment for representative visual treatment of data, and provides an interactive path for parameters and display refinement.

Electric Power Utility Application
An Electric Utility company in a major city is designing a specialized decision support application, coupling geospatial data models with advanced data visualization. The dual-aspect data source, interactive review, and the need to animate time history data generated requirements for a hybrid application design.

As the utility sector moves to a private, competitive marketplace, pressure is increased to effectively manage asset ROI and profit margins. Whereas Electric Utilities have traditionally managed power grids for long-life, reliability, redundancy in the case of failures, and over-designed duty cycles, the days of such long-term capital investment strategies are over.

Within the city, individual power transformers supply electricity to several blocks of residential & business customers. Typically each transformer is managed so that the power loading is at a fraction of its peak rating. In this way the life of the transformer is extended, and extra capacity is available for peak or emergency conditions. The closer the average load gets to the peak transformer rating, the shorter the equipment life cycle becomes. Striking the right balance between equipment cost, maintenance, and peak capacity is critical to obtaining a competitive supplier position.

The visualization application is designed specifically for this asset management and optimization problem. Historic transformer load data is accessed form a relational database. Transformer location, city map data, and spatial power consumption contours are derived from GIS sources. By choosing a near-peak day, such as when high temperatures indicate high air-conditioning usage, hour-by-hour load factor data can be seen in an animated geospatial view. Key problem areas can be easily identified by the visual representation. By clicking on an individual transformer or an aggregated region, detailed equipment information is displayed, using "drill down" techniques.

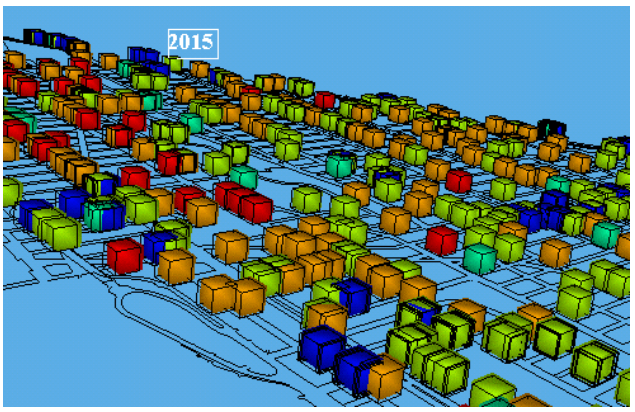

Figure 1, Transformer Load Factor View

The Electric Utility Company is able to plan and manage transformer upgrade and replacement programs much more effectively with a visualization-based decision support tool, giving managers a clear overview of critical load history data in a geo-located context.

Data Visualization In The Telecommunications Industry

Telecommunications companies have traditionally been quick to recognize the potential of new technology and use it to improve their business processes. Visualization systems allow users to see complex information displayed in ways they never before possible. As problems become more complex and as the patterns being searched for become more obscure, one-dimensional questions and two-dimensional reports simply fail to provide decision-makers with the input needed to understand the situation clearly. Visualization systems enable that change.

Visualization applications make it easy for engineers to see exactly what is happening in ways that no printed report can communicate. In some cases, products are used to watch current traffic patterns and flows through lines. Color, size and shape represent distinct load attributes on each section. In other cases, historical call detail data is accessed from geographic displays to pinpoint what kind of call activity is occurring and where [Mattison 97].

Cellular and PCS engineers use visualization tools to help isolate repeater and cell traffic problem nodes. Trouble spots and failed service reports are posted to a geographical mapping system, which includes the position, type, and orientation of each node. This combined data can be used to improve overloaded link-lines or multiplexers in the network.

The network capacity planning engineers need to understand the network capacity required based on the potential volume of calls the network must be able to carry without faults. In fact, most regulatory tariffs include a specification for the service level a carrier must provide to their customers.

One way customer service groups are using visual technology is to create visually based central clearing warehouses for all service-related activities. Using these facilities, dispatchers can get a 'birds-eye' view of where customers are having problems, the nature of those problems, and where the closest available service personnel can be located. Instant access to information reduces service call time, and improves the service provided to customers [Flavin 96].

The following three cases examine how data visualization has been applied by large telecommunications companies to solve data analysis issues associated with large repositories of spatial and network traffic data.

British Telecom

In the British Telecommunications (BT) network there are six thousand switches and twenty-five million customer lines generating megabytes of network status and control data every minute. Overlaid on the physical network is an expanding range of voice, data, and video services, each with their own data and management requirements. The main driver for rapid growth in visualization activity is the overwhelming volume of data that routinely confronts both researchers and managers.

An example of a visual network capacity planning tool is shown in figure 5. This application used for network performance analysis, call volume record pattern analysis, and planning for upgrades within the British Telecom network. The application front-ends a database, where call attributes are held, and ad-hoc queries are made. The principle view of the data is in a map-based display, where geographic regions such as managed network zones and exchanges are shown. Network nodes are shown as glyphs on the map, selectable via mouse gestures to generate SQL queries. As the user "drills in" to the call data detail, further views of call routing and route volume is shown both in tables and in a visual display.

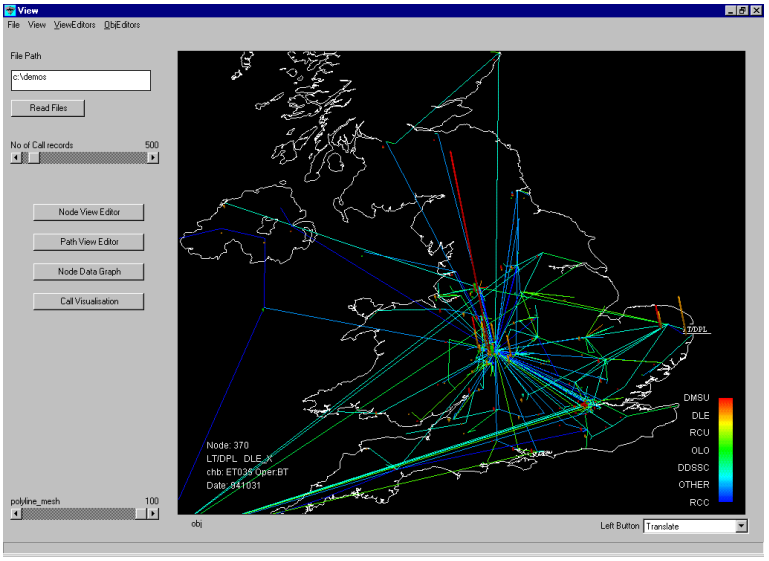

Figure 2 Regional Network Capacity Planning Tool

VODAFONE

Visualization software technology has enabled Vodafone, one of the UK's largest mobile telecommunications companies, to implement a system for monitoring cell coverage and network performance. The Vodafone Information System Analyzer is an intuitive application, which the engineering department is using extensively to monitor cell and network performance. Information that was once difficult to extract from multiple Oracle databases and required considerable SQL experience is now accessible through visual queries. For workers who rely on information, complex patterns in the data are immediately recognized and comprehended through the use of data visualization.

The application runs on UNIX and Windows platforms and provides a variety of views into the data, including vector and raster map information, 2D charts, and data tables. Users can interact with the display to select areas of interest and drill on more detailed information, such as the precise cell coverage in a dense urban area, as shown as a 3D view in Figure 7.

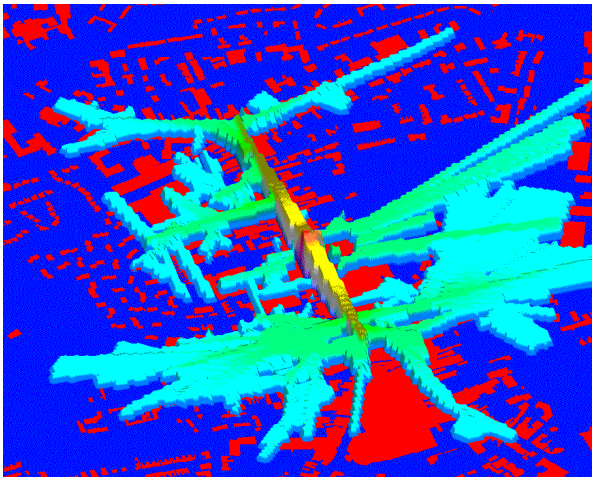

Figure 3 Detailed view of local signal strength

The network management application includes both geospatial map-based views as well as complimentary data visualization views seamlessly integrated into one user interface. With improved access to information, and visual representations of data that hasten comprehension, Vodafone has been able to improve product quality and service to customers on their mobile telephone network. In particular, critical systems monitoring through the Y2K period has proved the value of visualization in rapid problem identification.

Deutsche Telekom

Deutsche Telekom is the largest telecommunications service provider in Europe. Its position and reputation ensure that it will play a leading role in key technology developments into the next century, not least the global shift to the information-driven society and the worldwide liberalization of telecommunications.

In the ongoing quest for efficiency and cost-effective coverage, Deutsche Telekom continuously assesses all its existing and projected transmitters. In order to fine tune coverage footprints and avoid interference with other transmitters, data on factors such as land usage, road maps, population density, and simulations are all included in the analysis process. 3D views, similar to the image shown in Figure 4, provide the first approximation of the effect of variations in the surrounding terrain.

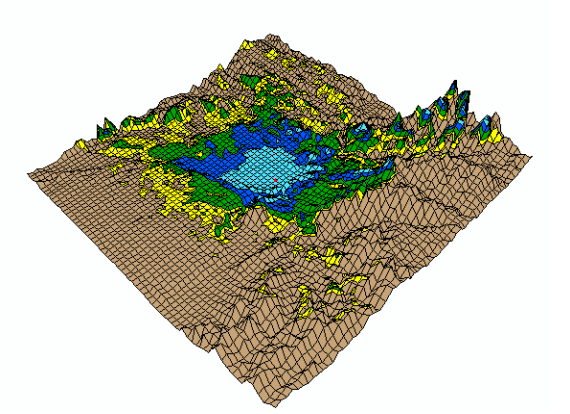

Figure 4 3D view of signal propagation using region decompression from LadMan

To assist planning engineers in providing optimal coverage, proposed transmitter sites are marked in Deutsche Telekom's GIS database and a wave propagation study, using Deutsche Telekom's AVS/Express-based application NetKo, is performed for the selected areas. The radiation propagation modeling tool shown in Figure 5, with its embedded data visualization capabilities, is being used at Deutsche Telekom to plan broadcasting coverage for the eastern part of Germany, as well as other countries worldwide.

With the emergence of new technologies, such as digital broadcasting, Deutsche Telekom is confident that the modeling system will enable it to mastermind the best possible solutions and meet the demands of all its customers. Visualization helps Deutsche Telekom technical specialists explore "what-if" scenarios and quickly arrive at valuable information, thus ensuring services that offer the greatest possible coverage at the lowest cost.

GIS applications, such as NetKo, are today producing and storing very large amounts of data, beyond what can be directly processed in visualization systems. To accommodate this situation, a specialized large data management layer (LadMan) was introduced to allow interactive visualization. The NetKo data is available through 2D Lat-Long coordinate fields. As the data covers a large part of Europe, the digital terrain and road maps consume more than 6 GBytes of uncompressed disk space. Using the LadMan subsystem, this data is stored in compressed form in 800 Mbytes.

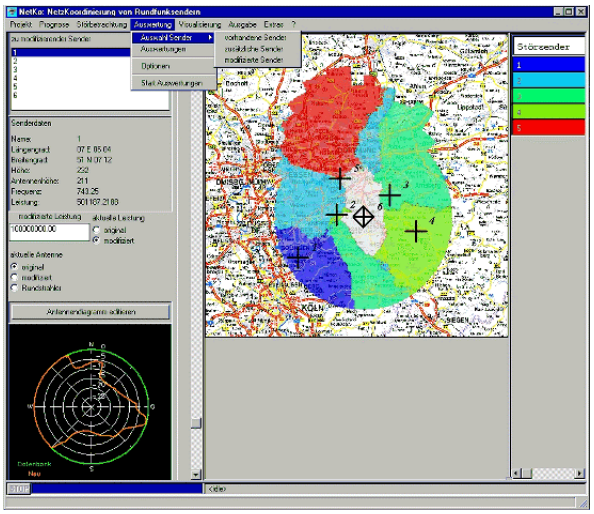

Figure 5 Radiation propagation modeling tool

The intelligent access methods of LadMan give the planning engineers easy access to all available data. It allows attributes at different resolutions to be blended into the same view. Zooming in and out for new views, or selecting maps at different scales is handled automatically. In addition, encryption layers are used to control access to data, so that decompression is only available to authorized persons [Schmeing 99].

CSC Radar Defense Application

Computer Science Corporation (CSC) Defense Group has applied a progressive non-traditional approach to military software development to produce the first of a new generation of visual and analysis tools for NORAD. MASC (Model for Analysis of Sensor Coverage) is a hybrid application containing both traditional GIS data and views with data visualization. MASC allows users to examine the relationships between radar coverage, terrain, and aircraft tracks using one integrated 2D and 3D visualization environment.

MASC contains a line-of-sight calculator that determines spatial coverage of air defense radar sites. For example, if a radar site goes down, an analyst can obtain a graphical view of the region, including other radar

sites operating in the area to assess vulnerability. The application is used for radar site planning, terrain masking of line-of-site communications, unmanning airborne vehicle (UAV) management, and satellite line-of-site masking.

The MASC software architecture is built on 3-tier client/server object oriented and component-based principles. An executive tier provides overall control, user interface, and component integration. The server tier is responsible for terrain data management, the line-of-site computational model, and advanced data visualization subsystem, and a relational database access system. The third tier is a set of data servers for terrain, coverage, and attribute data.

The visualization techniques included in MASC are 3D terrain contouring, grid reference overlays, aircraft track displays, and 3D spatial envelopes showing radar coverage. All visual elements in the scene are selectable, and further attribute data can be obtained directly with mouse interaction in the graphics window. The visualization software components are responsible for "fusing" data representations from multiple sources into a unified graphical environment.

The CSC radar application is a clear example of how geospatial and visualization technologies are integrated in a common view, and provide complimentary aspects to modern defense application [McHale 99].

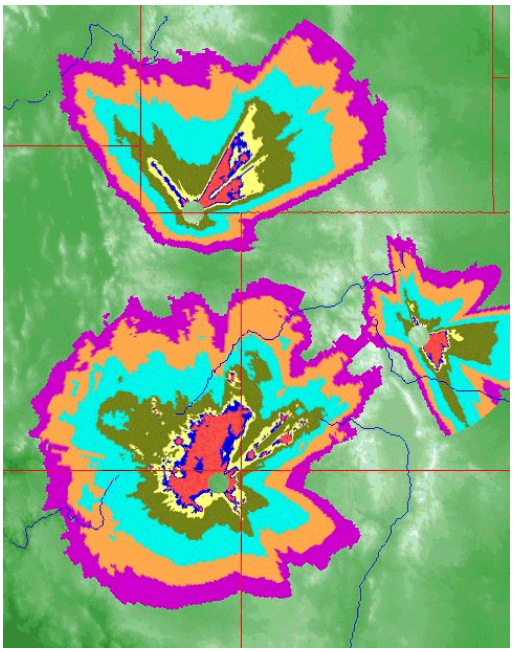

Figure 6 MASC Radar Coverage

Visualization with Multi-dimensional Spatial Databases

Geographical Information System tools can be used with spatially enabled databases to perform data queries and some level of spatial data analysis. Visualization tools differ from GIS tools in their support of multidimensional data structures. With visualization tools and data structures, complex data structures can be modeled and visually represented. The resulting display can include the GIS data for reference, but is not limited to a purely geographic view.

The spatial component of data can provide an important visual reference for selecting areas of interest for drill down. These interactive methods are often used in the early stages of the analysis process. A visualization tool can provide a spatial view of the data, and enable the user to drill down into further views of more abstract information not necessarily associated with a map.

Visualization applications are able to access multi-dimensional data from relational databases, and thus extend spatial analysis to a greater range of problem domains. As an example, AVS/Express extends 3D functionality beyond the surface modeling provided by typical GIS systems. In addition to its visualization techniques, It provides a true 3D data model that can be applied to a variety of multidimensional problems. AVS/Express uses a generic 3D data structure supporting a number of common mesh types. These are used to represent data from a broad range of application domains, such as imaging, engineering, defense, finance and telecommunications. Meshes can have many different forms, from the simplest uniform mesh having equidistant nodes and rectilinear meshes where node spacing is defined along the edges. At each node an unlimited number of attributes values can be present. With a visualization data model, visual data analysis, including spatial data components, can be applied to a variety of multi-dimensional problems.

These visual data representations are even more powerful when they can be interactively used to uncover additional sources of information. They support a two-way drawing pipeline that allows all graphics objects to serve as hotspots, or links, to further processing. Visual objects can be probed to reveal exact data values, or picked to drill down on finer grained views of the data. Interesting areas of the display can be selected and zoomed in on, or flown through for closer investigation.

Interactively enabled displays promote information discovery by enabling the viewer to pursue data relationships through multiple or modified views of the data. Each new view is invoked by intuitive use of the mouse. The power of many information discovery applications comes not from the use of sophisticated displays, but from the sophisticated use of display interactively to promote the data analysis process. In this respect, the

highly interactive nature of visualization tools offers a distinct functional advantage, even for data with a relatively low number of attributes.

The combination of spatial and multidimensional analysis provides an effective way to search for and identify important information and monitor critical business operations. Spatial information, such as that found in spatially enabled databases and geographic information systems, can provide important geographical reference points for data analysis and presentation. Visualization tools enable GIS-type information to be combined with multivariate information from business data repositories, and provide views and insight into data not obtainable from a purely geographical perspective. Spatial analysis combined with multidimensional data analysis in the same application is a powerful means of discovering information.

Approaches To GeoSpatial Application Deployment through RAD

The rapid visualization application development (RAD) system AVS/Express shields the user from data access commands by enabling data retrieval operations to be easily implemented as interaction with the display. AVS/Express provides modules that support the full functionality of Oracle from within its object-oriented, visual programming environment. Connectivity and transaction processing with the underlying SQL database can be fully implemented from within AVS/Express. The API to Oracle is encapsulated inside AVS/Express modules, enabling the connection to the database. Data access operations such as query and update are easily added to an application by inserting these modules into the visual application network. The AVS/Express network provides a high-level visual representation of the application logic.

In Figure 10, a visual application network is shown, including modules to access Oracle data. Modules are used to dynamically connect to Oracle and add data querying to the application. In this example, the data is extracted with a visual query to Oracle and visualized using a viewer module. The full functionality of Oracle Spatial Cartridge is accessible, but the API to Oracle is hidden from the user. An application built this way can be run, or modified, without compiling and linking [Schmidt 98].

The AVS/Express development system allows applications to be rapidly prototyped. In addition to the database connectivity and the application code, AVS/Express can also be used to develop cross-platform user interfaces. For example, menus and forms used for user input are easily constructed using the AVS/Express GUI kit, and can provide another interface for accessing data and controlling the application. When run under Windows, the AVS/Express-built application interface is instantiated as a Windows GUI; under UNIX the same application would have a Motif GUI.

From the AVS/Express environment, developers can also encapsulate existing legacy code, such as analysis algorithms written in FORTRAN, C, or C++. Once tested, the completed application can be output as a binary executable, or as C++ or ActiveX components. Deployment can be in the form of a new application, an application component, or a web-based client-server implementation.

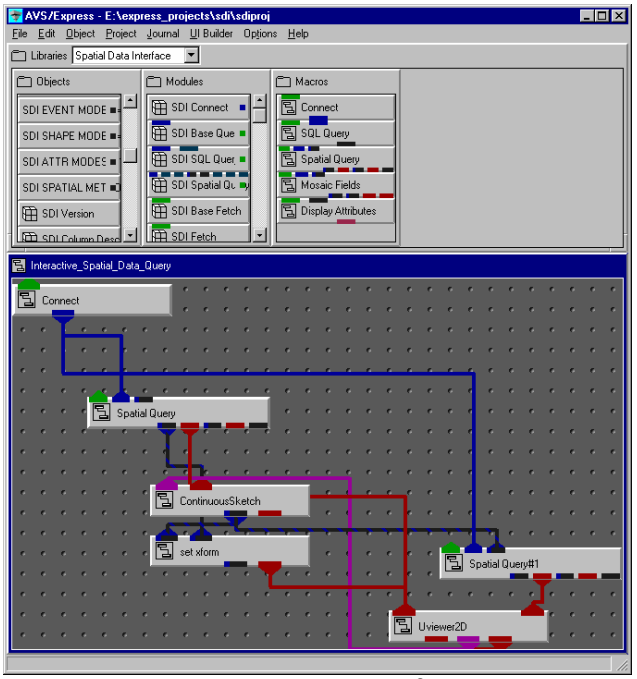

Figure 7 Visual construction of Oracle Spatial Cartridge in a visualization application

Conclusion

By coupling geospatial data access methods and analysis operations with interactive visualization technology, applications are constructed that allow direct graphical manipulation and understanding of key data relationships. Organizations with large geospatial repositories can rapidly develop and deploy applications that allow visual selection, query and interaction. A number of case examples from Electric Utility, Telecommunications, and Defense areas show how these methods are put into practice.

About Advanced Visual Systems

Advanced Visual Systems Inc. (AVS) is the premiere global provider of sophisticated data visualization solutions that transform massive and complex quantities of data into visual representations. The company

provides solutions for developers who build customized visualization software, as well as ready-to-use applications for end users who analyze information contained in graphical representation.

More than 12,000 organizations around the world use AVS solutions to gain insight and competitive advantage from data. They look to AVS to reduce development costs, incorporate industry standards, and speed time to market. Detailed information related to this paper may be found on http://www.avs.com .

Ian Curington is a founder-member of Advanced Visual Systems, and is responsible for world-wide technical and application marketing.

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