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Current Trends and Applications of Visualisation in Geoinformatics

Dr. Deshmukh Nilesh Kailasrao*
School of Computational Sciences,
Swami Ramanand Teerth Marathwada Univrsity,Nanded(MH), India
nileshkd@yahoo.com

Abstract—**The success of direct-manipulation interfaces is indicative of the power of using computers in a more visual or graphic manner. A picture is often cited to be worth a thousand words and, for some (but not all) tasks, it is clear that a visual presentation - such as a map or photograph is dramatically easier to use than is a textual description or a spoken report. As computer speed and display resolution increase, information visualization and graphical interfaces are likely to have an expanding role.**

Spatial data is a general term that refers to data describing the location, shape, and spatial relationships of anything, from engineering drawings to maps of galaxies. Geospatial data is spatial data that is in some way geo-referenced, or tied to specific locations on, under, or above the surface of a planet.

Geoinformatics is the science and the technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering. Some times it may be refered to as geospatial informatics.

This paper present an overview on current trends and applications of visualisation in geoinformatics. It also focus on available techniques for visualisation of spatial data.

Keywords— **Visualisation; Geoinformatics; Surface rendering; Volume rendering; Geovisualisation; Visual dimension**

I. INTRODUCTION

Spatial data is a general term that refers to data describing the location, shape, and spatial relationships of anything, from engineering drawings to maps of galaxies. Geospatial data is spatial data that is in some way geo-referenced, or tied to specific locations on, under, or above the surface of a planet [1].

Geoinformatics is the science and the technology which develops and uses information science infrastructure to address the problems of geography, geosciences and related branches of engineering. Some times it may be refered to as geospatial informatics.

Geoinformatics has been described as "the science and technology dealing with the structure and character of spatial information, its capture, its classification and qualification, its storage, processing, portrayal and dissemination, including the infrastructure necessary to secure optimal use of this information" or "the art, science or technology dealing with the acquisition, storage, processing production, presentation and dissemination of geoinformation"[1].

Geomatics is a similarly used term which encompasses geoinformatics, but geomatics focuses on surveying. Geoinformatics has at its core the technologies supporting the processes of acquiring, analyzing and visualizing spatial data. Both geomatics and geoinformatics include and rely heavily upon the theory and practical implications of geodesy.

Geography and earth science increasingly rely on digital spatial data acquired from remotely sensed satellite images analyzed by GIS and visualized on paper or the computer screen.

Geoinformatics combines geospatial analysis and modeling, development of geospatial databases, information systems design, human-computer interaction and both wired and wireless networking technologies. Geoinformatics uses geocomputation and geovisualization for analyzing geoinformation.

Many fields of human activities benefit from Geoinformatics, including urban planning and land use management, in-car navigation systems, virtual globes, public health, local and national gazetteer management, environmental modeling and analysis, military, transport network planning and management, agriculture, meteorology and climate change, oceanography and coupled ocean and atmosphere modeling, business location planning, architecture and archeological reconstruction, telecommunications, criminology and crime simulation, aviation and maritime transport.

The success of direct-manipulation interfaces is indicative of the power of using computers in a more visual or graphic manner. A picture is often cited to be worth a thousand words and, for some (but not all) tasks, it is clear that a visual presentation - such as a map or photograph is dramatically easier to use than is a textual description or a spoken report.

As computer speed and display resolution increase, information visualization and graphical interfaces are likely to have an expanding role. If a map of the India is displayed, then it should be possible to point rapidly at one of the large number of cities to get tourist information. Of course, a foreigner who knows a city's name (for example, Latur), but not its location, may do better with a scrolling alphabetical list. Visual displays become even more attractive to provide orientation or context, to enable selection of regions, and to provide dynamic feedback for identifying changes (for example, a weather map). In engineering applications, scientific visualization has the power to make atomic, cosmic, and common three-dimensional phenomena (such as heat conduction in engines, airflow over wings, or ozone holes) visible and comprehensible. In general, abstract information visualization has the power to reveal patterns, clusters, gaps, or outliers in statistical data, stock-market trades, computer directories, or document collections [2].

II. VISUAL DIMENSIONS

A. 1-dimensional

The linear data types include textual documents, program source code, and alphabetical lists of names which are all organized in a sequential manner. Each item in the collection is a line of text containing a string of characters. Additional line attributes might be the date of last update or author name. Interface design issues include what fonts, color, and size to use and what overview, scrolling, or selection methods can be used. User problems might be to find the number of items or patterns.

B. 2-dimensional

The planar or map data include geographic maps, floor plans, or newspaper layouts. Each item in the collection covers some part of the total area and may be rectangular or not. Each item has task-domain attributes such as name, owner, value, etc. and interface-domain features such as size, color, opacity, etc. While many systems adopt a multiple layer approach to deal with map data, each layer is 2-dimensional. User problems are to find adjacent items, containment of one item by another, paths between items, and the basic tasks of counting, filtering, and details-on-demand.

Geographic Information Systems constitute a large research and commercial domain with numerous systems available. Information visualization researchers have used spatial displays of document collections organized proximally by term co-occurrences.

C. 3-dimensional

The real-world objects such as molecules, the human body, Geo surface models, and buildings have items with volume and some potentially complex relationships with other items. Computer-assisted design systems for architects, solid modelers, and mechanical engineers are built to handle complex 3-dimensional relationships. User's tasks deal with adjacency plus above/below and inside/outside relationships, as well as the basic tasks. In 3-dimensional applications, users must cope with understanding their position and orientation when viewing the objects, plus the serious problems of occlusion. Solutions to some of these problems are proposed in many prototypes with techniques such as overviews, landmarks, perspective, stereo display, transparency, and color coding.

Three-dimensional computer graphics and computer-assisted design are large topics, but information visualization efforts in three dimensions are still novel, and navigating high resolution images of the objects are the challenges.

D. Temporal

The time lines are widely used and vital enough for medical records, project management, or historical presentations to create a data type that is separate from 1-dimensional data. The distinction in temporal data is that items have a start and finish time and that items may overlap. Frequent tasks include finding all events before, after, or during some time period or moment, plus the basic tasks.

E. Multi-dimensional

The most relational and statistical databases are conveniently manipulated as multi-dimensional data in which items with n attributes become points in a n-dimensional space. The interface representation can be 2-dimensional scatter grams with each additional dimension controlled by a slider. Buttons can used be for attribute values when the cardinality is small, say less than ten. Tasks include finding patterns, clusters, correlations among pairs of variables, gaps, and outliers. Multi-dimensional data can be represented by a 3-dimensional scatter gram but disorientation (especially if the user’s point of view is inside the cluster of points) and occlusion (especially if close points are represented as being larger) can be problems. The technique of parallel coordinates is a clever innovation which makes some tasks easier, but takes practice for users to comprehend.

Practical application of information visualization in computer programs involves selecting, transforming and representing abstract data in a form that facilitates human interaction for exploration and understanding. Important aspects of information visualization are the interactivity and dynamics of visual representation. Strong techniques enable the user to modify the visualization in real-time, thus affording unparalleled perception of patterns and structural relations in the abstract data in question.

The use of visualization to present information is not a new phenomenon. It has been used in maps, scientific drawings, and data plots for over a thousand years. Examples from cartography include Ptolemy's Geographia (2nd Century AD), a map of China (1137 AD), and Minard's map (1861) of Napoleon's invasion of Russia half a century earlier. Most of the concepts learned in devising these images carry over in a straight forward manner to computer visualization. Edward Tufte has written two critically acclaimed books that explain many of these principles.

Computer graphics has from its beginning been used to study scientific problems. However, in its early days, the lack of graphics power often limited its usefulness. The recent emphasis on visualization started in 1987 with the special issue of Computer Graphics on Visualization in Scientific Computing. Since then there have been several conferences and workshops, co-sponsored by the IEEE Computer Society and ACM SIGGRAPH, devoted to the general topic, and special areas in the field, for example volume visualization.

Most people are familiar with the digital animations produced to present meteorological data during weather reports on television, though few can distinguish between those models of reality and the satellite photos that are also shown on such programs. TV also offers scientific visualizations when it shows computer drawn and animated reconstructions of road or airplane accidents. Some of the most popular examples of scientific visualizations are computer-generated images that show real spacecraft in action, out in the void far beyond Earth, or on other planets. Dynamic forms of visualization, such as educational animation, have the potential to enhance learning about systems that change over time.

Apart from the distinction between interactive visualizations and animation, the most useful categorization is probably between abstract and model-based scientific visualizations. The abstract visualizations show completely conceptual constructs in 2D or 3D. These generated shapes are completely arbitrary. The model-based visualizations either place overlays of data on real or digitally constructed images of reality, or they make a digital construction of a real object directly from the scientific data.

Scientific visualization is usually done with specialized software, though there are a few exceptions, noted below. Some of these specialized programs have been released as open source software, having very often its origins in universities, within an academic environment where sharing software tools and giving access to the source code is common. There are also many proprietary software packages of scientific visualization tools. Models and frameworks for building visualizations include the data flow models popularized by systems such as Advanced Visual System (AVS), Illinois Researcher Information Service (IRIS) Explorer, and the Visualization Toolkit (VTK), and data state models in spreadsheet systems such as the Spreadsheet for Visualization and Spreadsheet for Images.

III. VISUALIZATION TECHNIQUES

In the last few years, the increasing volume of information provided by several applications, different instruments and mainly the web has lead to the development of techniques for selecting, among a bulk of data, the subset of information that is relevant for a particular goal or need. Research on visual query systems, data mining and interactive visualization techniques has resulted in a wide variety of visual presentation and interaction techniques that can be applied in different situations. However, although there is a great variety of models and techniques for information visualization, each application requires a particular study in order to determine if the selected technique is useful and usable. The type of data that should be represented and the user tasks, and analysis process that the visualization should help or support usually guides these studies. By observing several applications, it has become evident that we cannot separate the visual aspects of both data representation and graphical interface from the interaction mechanisms that help a user to browse and query the data set through its visual representation. Moreover, it is clear that evaluating these two aspects is an important issue that must be addressed with different approaches including, of course, empirical tests with users. Potential users of information visualization often have their own analysis tools and are not aware of the benefits of visualization techniques as a first phase in the data analysis process. Besides visual representation characteristics and interaction mechanisms, a third aspect should concern the use of an information visualization technique as the core of an application interface: data usability.

Usually, usability is a term employed to describe the quality of use of applications by end-users. In the context of interfaces for information visualization, user not only interact with widgets on the interface but also with data supporting decision-making, which could be affected by the way information is presented. Due to the nature of gathering or processing data, noise could be included in the data set affecting original data. In addition, a huge amount of information must be cut and summarized to be useful for supporting decision-making; even though the kind of information processing could alter the quality of original data set. These problems are not related to interaction mechanisms provided by the interface but with the data processing itself. That is why we use the term data usability to describe quality of information or quality of data in the context of information visualization applications.

Data usability is associated to three principles:

• data reliability, which describes the feasibility of the gathering data process as well as the confidence level, including interval for errors, etc. that can cause distortion between reality and model (reality represented by the system);

• Minimal impact on data changing, i.e., the system must avoid changing the information and it must allow recovering original information whenever it is needed. However, in practice, this data stability is not feasible because frequently data must have to be adapted to visualization constraints such as the reduction of dimension, for example, when presenting n-dimensional data in a 2D or 3D visualization, this 2D or 3D representation breaks down the usability of original data. It is clear that we cannot avoid some changes during the visualization process but we can try to reduce their impact; and,

• Support decision-making, which means that data representation should be understandable by end-users and help them to make decisions. Since information visualization is intended to provide insight from data, it becomes clear that both visual representation and interaction techniques must not affect the ways the user needs to use the data in a variety of analysis procedures.

Based on the above discussion, one can separate usability issues in three main categories: i) visual representation usability, referring the expressiveness and quality of the resulting image; ii) interface usability, related to the set of interaction mechanisms provided to users, so that they can interact with data through the visual representation; and, iii) data usability, devoted mainly to the quality of data for supporting users' tasks. The approach is to link interface usability knowledge, concepts and methods with evaluation of the expressiveness, semantic content, and interaction facilities of visualization techniques. The first step was to define criteria for the evaluation of visual representations and interaction mechanisms provided by different techniques. Classical techniques employed for evaluating user interfaces (for example, usability inspection methods and user testing) are being investigated to select an adequate framework for a methodology of usability testing at all the three levels mentioned above. At present, there are empirical evidences collected from case studies suggesting that one can distinguish these three categories.

A last subset of criteria is related to the data set reduction features provided by the technique. Filtering allows reduction of information shown at a certain moment, leading more rapidly to adjustment of the focus of interest, and clustering allows representing a subset of data elements by means of special symbols, while pruning simply cuts off information irrelevant for the understanding of a visual representation [3].

IV. INFORMATION VISUALIZATION

Scientists, engineers, medical personnel, business analysts, and others often need to analyze large amounts of information or to study the behavior of certain processes. Numerical simulations carried out on supercomputers frequently produce data files containing thousands and even millions of data values. Similarly, satellite cameras and other sources are amassing large data files faster than they can be interpreted. Scanning these large sets of numbers to determine trends and relationships is a tedious and ineffective process. But if the data are converted to a visual form, the trends and patterns are often immediately apparent. The Fig.1 shows an example of a large data set that has been converted to a color-coded display of relative heights above a ground plane. Once we have plotted the density values in this way, we can see easily the overall pattern of the data. Producing graphical representations for scientific, engineering, and medical data sets and processes is generally referred to as scientific visualization. The term business visualization is used in connection with data sets related to commerce, industry, and other nonscientific areas.

There are many different kinds of data sets, and effective visualization schemes depend on the characteristics of the data. A collection of data can contain scalar values, vectors, higher-order tensors, or any combination of these data types. A data set can be two-dimensional or three-dimensional. Color coding is just one way to visualize a data set. Additional techniques include contour plots, graphs and charts, surface renderings, and visualizations of volume interiors. In addition, image processing techniques are combined with computer graphics to produce many of the data visualizations.

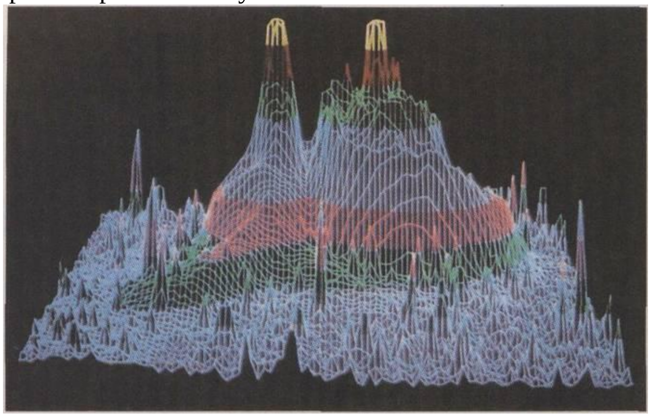
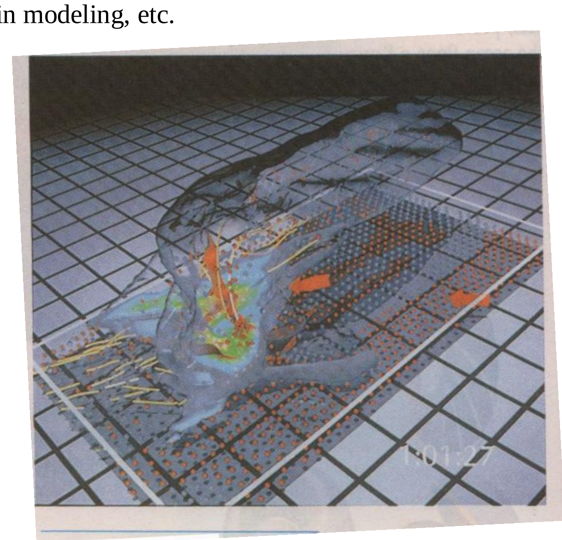


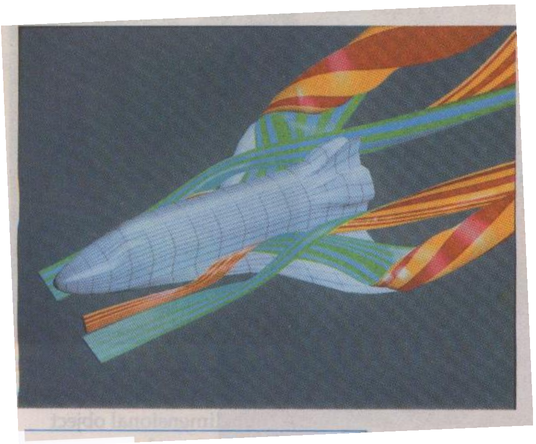
Fig.1 A color-coded plot with 16 million density points of relative brightness observed for the Whirlpool Nebula reveals two distinct galaxies. (Courtesy of Los Alamos National Laboratory.)

Mathematicians, physical scientists, and others use visual techniques to analyze mathematical functions and processes or simply to produce interesting graphical representations.

Scientists are also developing methods for visualizing general classes of data. A few of the many other visualization applications are airflow over the surface of a space shuttle (Fig.9(a)&(b)), numerical modeling of thunderstorms, study of crack propagation in metals, a color-coded plot of fluid density over an airfoil, a cross-sectional slicer for data sets, protein modeling, etc.



(a)



(b)

Fig.2 (a) & 2 (b) visualization of stream surfaces flowing a space shuttle by Jeff Hultquist and Eric Raible, NASA Ames. (Courtesy of Sam Uselton, NASA Ames Research Center.).

F. Visualization of large databases

Never before in history, data has been generated at such high volumes as it is today. Exploring and analyzing the vast volumes of data becomes increasingly difficult. Information visualization and visual data mining can help to deal with the flood of information. The advantage of visual data exploration is that the user is directly involved in the data mining process. There are large numbers of information visualization techniques which have been developed over the last decade to support the exploration of large data sets [4].

G. Visual points system

In a large number of applications, data are collected and referenced by their spatial locations.

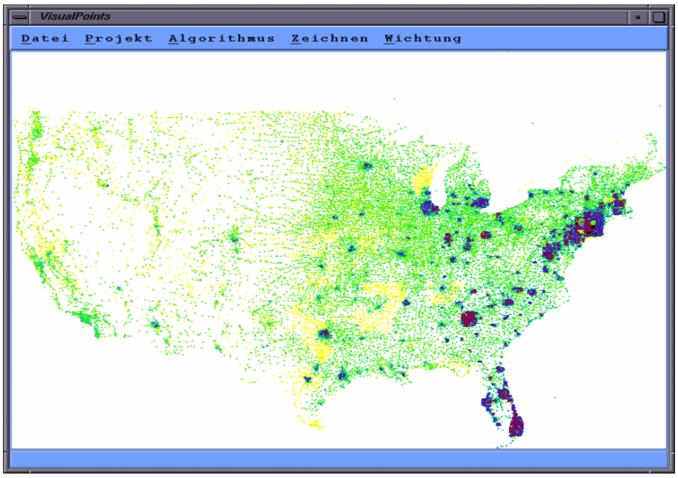


Fig.2 Visualization of large data on small

Visualizing large amounts of spatially referenced data on a limited-size screen display often results in poor visualizations due to the high degree of over plotting of neighboring data points. The Visual Points System (VPS) implements a new approach to visualizing large amounts of spatially referenced data as shown in Fig.3.

H. Visualization of data sets

Use of graphical methods as an aid in scientific and engineering analysis is commonly referred to as scientific visualization. This involves the visualization of data sets and processes that may be difficult or impossible to analyze without graphical methods. For example, visualization techniques are needed to deal with the output of high-volume data sources such as supercomputers, satellite and spacecraft scanners, radio-astronomy telescopes, and medical scanners. Millions of data points are often generated from numerical solutions of computer simulations and from observational equipment, and it is difficult to determine trends and relationships by simply scanning the raw data, Similarly, visualization techniqs are useful for analyzing processes, that occur over a long time period or that cannot be observed directly, such as quantum-mechanical phenomena and special-relativity effects produced by objects traveling near the speed of light. Scientific visualization uses methods from computer graphics, image processing, computer vision, and other areas to visually display, enhance, and manipulate information to allow better understanding of the data. Similar methods employed by commerce, industry, and other nonscientific areas are sometimes referred to as business visualization.

Data sets are classified according to their spatial distribution and data type. Two-dimensional data sets have values distributed over a surface, and three-dimensional data sets have values distributed over the interior of a cube, a sphere, or some other region of space. Data types include scalars, vectors, images, and multivariate data.

I. Visual representations for vector fields

A vector quantity V in three-dimensional space has three scalar values (Vx, Vy Vz,), one for each coordinate direction, and a two-dimensional vector has two components (Vx ,Vy). Another way to describe a vector quantity is by giving its magnitude | V | and its direction as a unit vector u. As with scalar, vector quantities may be functions of position, time, and other parameters. Some examples of physical vector quantities are velocity, acceleration, force, electric fields, magnetic fields, gravitational fields, and electric current.

One way to visualize a vector field is to plot each data point as a small arrow that shows the magnitude and direction of the vector. This method is most often used with cross-sectional slices, as in Fig.3, since it can be difficult to see the data trends in a three-dimensional region cluttered with overlapping arrows. Magnitudes for the vector values can be shown by varying the length of the arrows, or one can make all arrows the same size, but make the arrows different colors according to a selected color coding for the vector magnitudes.

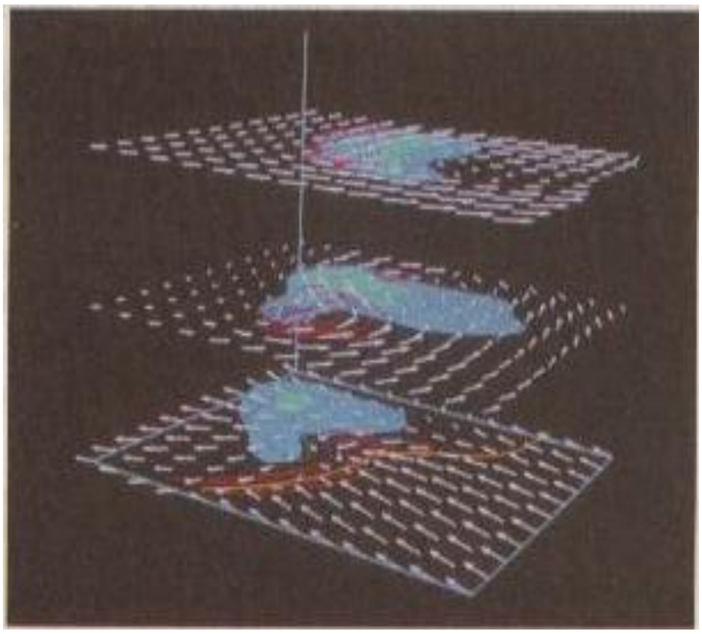


Fig.3 Visualization of cross-sectional slice layers.

V. SCIENTIFIC VISUALIZATION.

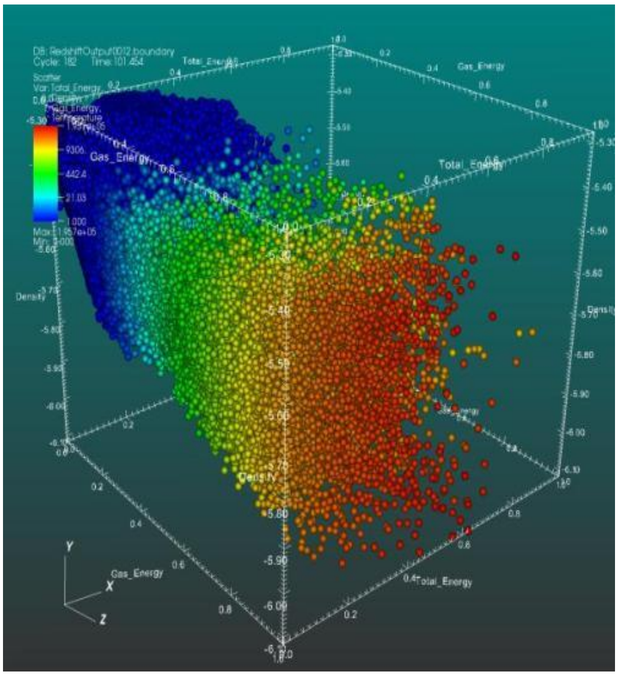


Fig.4 A scientific visualization using scatter plot.

Scientific visualization is an interdisciplinary branch of science, according to Michael Friendly (2008), "primarily concerned with the visualization of three dimensional phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component". A simple example of a scientific visualization using scatter plot is shown in Fig.4. Followings are few topics covered under scientific visualization [5].

A. Surface rendering

Rendering is the process of generating an image from a model, by means of computer programs. The model is a description of three dimensional objects in a strictly defined language or data structure. It would contain geometry, viewpoint, texture, lighting, and shading information. The image is a digital image or raster graphics image. The term may be by analogy with an "artist's rendering" of a scene. 'Rendering' is also used to describe the process of calculating effects in a video editing file to produce final video output.

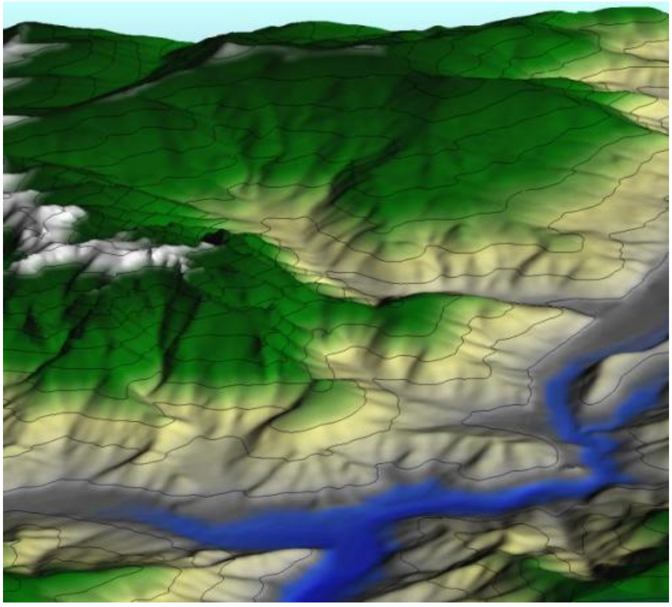


Fig.5 Terrain Rendering

A high-level representation of an image necessarily contains elements in a different domain from pixels. These elements are referred to as primitives. In a schematic drawing, for instance, line segments and curves might be primitives. In a graphical user interface, windows and buttons might be the primitives. In 3D terrain rendering, triangles and polygons in space might be primitives. A simple example of 3D rendering is shown in Fig.5 [6].

B. Volume rendering

Volume rendering is a technique used to display a 2D projection of a 3D discretely sampled data set. A typical 3D data set is a group of 2D slice images acquired by a CT or MRI scanner. Usually these are acquired in a regular pattern (e.g., one slice every millimeter) and usually have a regular number of image pixels in a regular pattern. This is an example of a regular volumetric grid, with each volume element, or voxel represented by a single value that is obtained by sampling the immediate area surrounding the voxel.

C. Volume visualization

The volume visualization examines a set of techniques that allows viewing an object without mathematically representing the other surface. Initially used in medical imaging, volume visualization has become an essential technique for many sciences, portraying phenomena become an essential technique such as clouds, water flows, and molecular and biological structure. Many volume visualization algorithms are computationally expensive and demand large data storage. Advances in hardware and software are generalizing volume visualization as well as real time performances [7].

VI. Conclusion

Like the related fields of scientific visualization and information visualization, geovisualization emphasizes knowledge construction over knowledge storage or information transmission. To do this, geovisualization communicates geospatial information in ways that, when combined with human understanding, allow for data exploration and decision-making processes.

Traditional, static maps have a limited exploratory capability; the graphical representations are inextricably linked to the geographical information beneath. GIS and geovisualization allow for more interactive maps; including the ability to explore different layers of the map, to zoom in or out, and to change the visual appearance of the map, usually on a computer display. Geovisualization represents a set of cartographic technologies and practices that take advantage of the ability of modern microprocessors to render changes to a map in real time, allowing users to adjust the mapped data on the fly.

Geovisualization has made inroads in a diverse set of real-world situations calling for the decision-making and knowledge creation processes. Today the geovisualization is able to process multidimensional data of different formats and can explore the extracted knowledge into different ways.

References

[1] KLN Murthy, *Applied Geoinformatics*, M.D. Publications, Jaipur (India), 2007.

[2] Donald Hearn and M.Paulin Baker, *Computer Graphics, C version*, 2nd ed., Pearson Education, Singapore, 2002.

[3] William D. Stanley, *Technical Analysis and Applications with MATLAB*, India ed., Cengage learning, New Delhi, 2008.

[4] Benjamin B. Bederson and Ben Shneiderman, The *Craft of Information Visualization: Readings and Reflections*. Morgan Kaufmann, San Fransisko, 2003.

[5] Charles D. Hansen and Chris Johnson, *Visualization Handbook*, Academic Press, New York, June 2004.

[6] Bastin L., Fisher, P.F. and Wood, J., “Visualizing Uncertainty in Multi-Spectral Remotely Sensed Imagery.” Computers & Geosciences, 28(3), 2002, pp. 337-350

[7] Rosenblum, Lawrence J, *Visualization in scientific computing*, IEEE Computer Society Press, Los Alamitos, Calif, 1990.

