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Geo-Visualization: Current Issues / Future Potentials

Visualization

Visualization of geographical information has been termed 'geo-visualization'. In comparison, 'information visualization' applications involve, for example, data mining applications. 'Scientific visualization' involves the rendering of scientific results and research. Those involved with the perception of visualizations often speak about 'cognitive visualization' where, those factors related to human perception and ability to identify objects visually - are studied and considered.

By far, the largest use of GIS today involves 2-D datasets (x, y) where rendered output most closely follows traditional cartographic representation, resembling the paper map. In (Fig 1.) are a number of discrete points in space – in 2-D. Though each point has both an (x) and (y) coordinate, it remains uncertain if the viewpoint is orthographic – from the top down or the points are actually being viewed from an alternate angle. Those familiar with Virtual Reality Markup Language (VRML), know that rendering of these points in VRML will allow the viewer to move about the points – turning them and flipping them so that they appear to be viewed from an alternate angle. In (Fig. 2), the points appear in 3-D but are actually in 2-D, though the perspective has changed. Where exactly is the X-axis - or the Y-axis, in the second figure? One researcher published a book entitled 'How to Lie with Maps' ( ), which provides numerous examples about how data can be represented graphically and lead to differences in understanding the representation of data – a very intriguing book. Visualization is useful for exploration, analysis and the communication of knowledge about spatial information (Kraak and Ormeling, 1996).

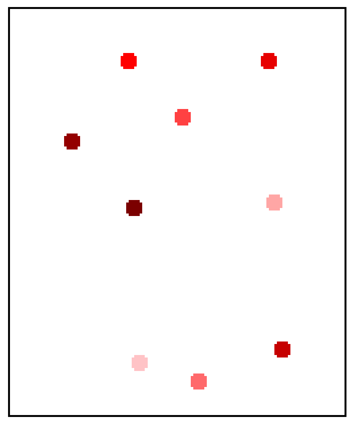


Fig. 1 - 2D coordinates

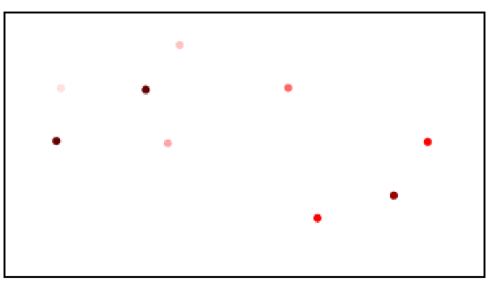


Fig. 2 - 2D coordinates from an alternate perspective

Continuing with the above example, it is only when information is 'communicated' to the viewer, about where the axis, scale or other aspatial information about the points, that they can truly be understood with respect to position and in the context that they are presented. Alternatively, if a third axis (z) is identified and rendered, then the visualized points assist the viewer to gain an understanding of the viewpoint. In (Fig. 3), a third axis is presented, simply, by extruding the individual points, thereby providing a reference indicating where their individual bases are. While I have extruded the values for each point, they could, for example, represent values for population, levels of soil contamination, business locations with numbers of customers, number of sunny days or even represent the numbers of people in a region who like GIS and visualization as I do. The possibilities are endless. These examples are rudimentary, but capture the basic concepts of GIS and visualization well.

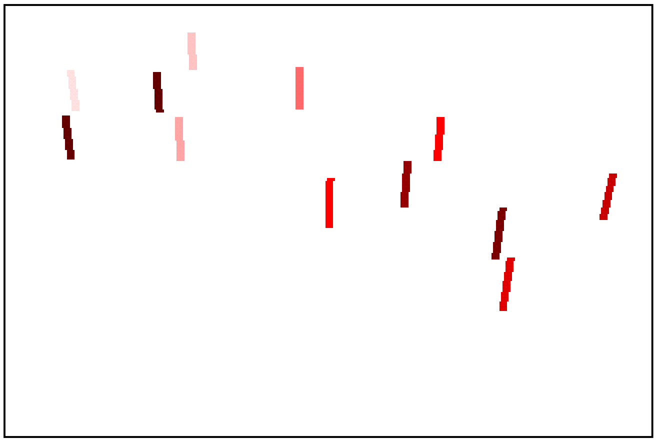


Fig. 3 - 3D coordinates providin perspective reference

Representation

There is a growing international trend toward the capture of 3-D information (x, y, z) in both urban and rural locations, involving a wide array of disciplines and applications. GIS users have been at the forefront in the development of these applications, which include business, telecommunications, agriculture, forestry, entertainment, demographics and a host of other areas in both real-time and near real-time applications. The importance and usefulness of 2-D GIS applications predominately involve network analysis and spatial operations, for the purposes of determining shortest paths, buffering and spatial statistics - such as how many customers live near a coordinate or within a specified distance of a building or business.

The representational tools used in geo-representation for the most part, are primarily, derived from database design and from geometry (Molenaar, 1998). These databases may take the form of flat files, networked or relational databases. Database records identify points in vector models or grid squares in a raster matrix. A series of points form lines and a line closing upon itself constitutes a polygon. Object oriented databases are available, however, for the most part, they are not prominent in geo-visualization applications, though they hold great promise where the coupling of models to GIS are involved. Such coupling will grow increasingly.

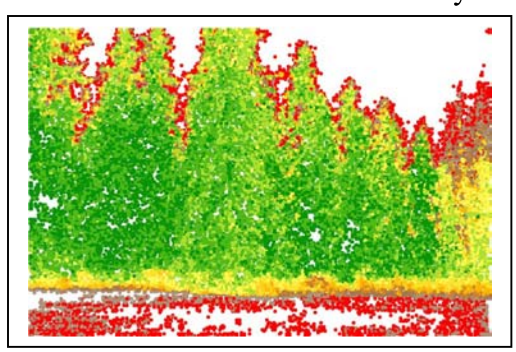
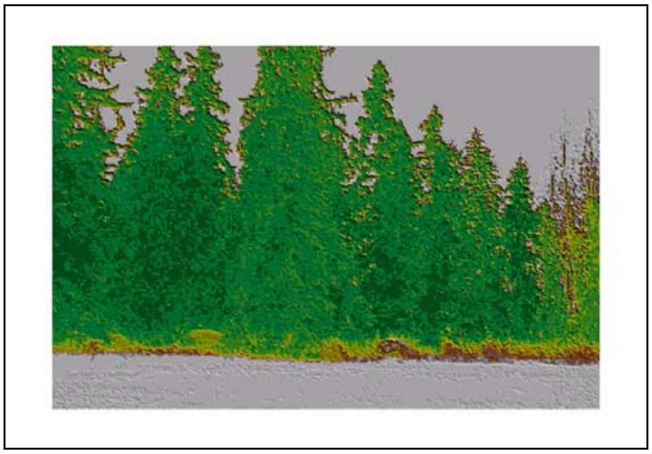


Fig. 4 - 3D thematic height fields

While the viewer can move around both 2-D and 3-D thematic layers in a VRML representation, a few considerations are noted.

Firstly, to construct a thematic layer means querying a data table, which will present the information to be rendered. (Fig. 4) is an example of 'Vertical GIS', a technique I am currently developing - the image is of a forested area. In this example, images were collected from side-view using a number of geo-technologies including GPS, laser, photogrammetry techniques and image analysis software for the purpose of understanding and exploring biodiversity indicators. One of the goals in this case is to explore the structure of objects and perhaps to communicate to others, some information about forest structure. To do this, the thematic layer could be converted to a triangulated irregular network (TIN) allowing for a 3-D representation of the surface (Fig 5.). The landscape has been classified using unsupervised techniques and appears to visually represent the forest structure well.



Similar to a digital elevation model (DEM), this representation might instead be called a 'vegetation distance model' (VDM) - since elevation is actually measured as distance. It is at this point, that we move from GIS into visualization – for the purpose of exploring the image. In (Fig. 6) the pixel height fields, as determined by laser distance measurement, are viewed from (Fig. 4) in ArcView 3D Analyst. The perspective has changed and the pixel height fields for each classification are now displayed. The viewer can alter the perspective angle, and if the values are extruded further and displayed in VRML, then it is possible to move through a representation of the actual forest structure. For the cartographer, this image raises a certain question – since no apparent scale is present. Therefore it is not possible to determine areal distances, which explains why visualization is used primarily for communication and exploration. The visualization can be explored and talked about and the viewer can move around the individual pixels particularly if the image were rendered in an environment capable of providing stereoscopic viewing, such as a CAVE.

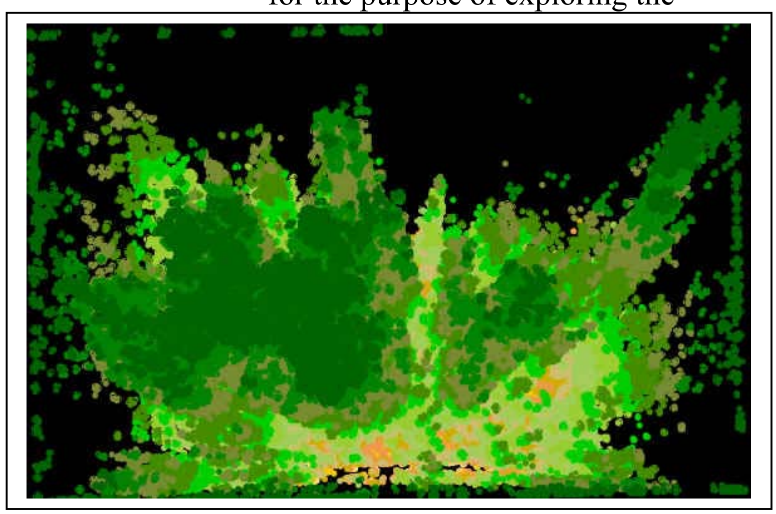


Fig. 6 - 3D height fields in ArcView 3D Analyst for visual exploration of forest structure

Coupling, Immersion and Interactivity

Current GIS 3-D representation does not truly exist. Many existing GIS models are actually modeling a 2.5-D environment. The modeled objects, while visible in 3-D, have an underlying data structure more closely resembling 2-D topology. That is, the appearance of objects, are relative to the viewer as compared to the objects themselves (MacEachren, 1995). An example of this can be found in rendering a building in a GIS in 3-D (2.5-D), where it can be noticed that window sills are not, usually visible. Animations, from GIS thematic layers are created, by querying then rendering a series of queries - pasting them together frame by frame.

In practice, this means the GIS user poses a query and displays the thematic content, exporting the result into a visualization software package such as VTK, 3D Studio Max, VRML, MAYA, World Construction Set, Visual Data Explorer or other such similar software. In such a case, the user cannot query the thematic content in the visualization software, but must export (or generate) a new thematic layer back in the GIS software. This explains why a closer coupling between GIS and visualization would be useful. Again, GIS are database focused while visualization is rendering oriented. Visualization, while allowing for communication and exploration, does not currently provide the robust functionality found in common GIS software packages. Spatial operations, thematic overlay, network analysis and principle component analysis, for example, all remain entrenched in GIS. On the other hand, rich lighting effects, morphing, NURBS and the numerous rendering capabilities are primary to a visualization domain. Due to the fact, that GIS evolved from the database and visualization evolved from computer graphics, visualization emulates the camera while GIS is, related more to the database (Thurston et al, 2001). Currently GIS users are increasingly attempting to render more photo-realistic images. To accomplish this, users are draping aerial photography, satellite images and digital photographs over digital elevation models, or pasting photo-realistic 'textures' to polygons to increase levels of realism.

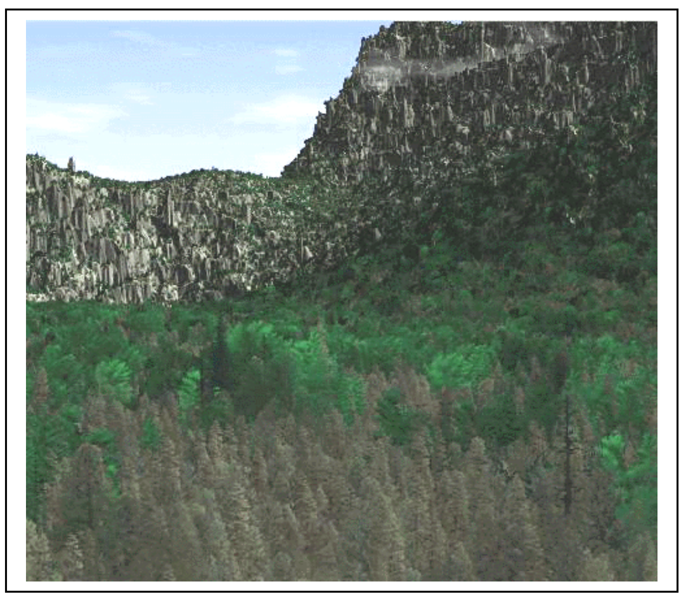


Fig. 7 – Diseased trees rendered for exploration.

Higher levels of photo-realism result in higher degrees of interactivity, an important factor when trying to communicate information, for learning, research and to enhance group discussion. Consequently, it is not surprising that GIS users are embracing visualization to convey their message for purposes of urban planning, business, landscape change, demographics and health related issues among other possibilities. But the question remains, how do we increase levels of photo-realistic rendering, which include cartographic accuracy, while at the same time permitting dynamic database interaction? A few individuals and organizations are exploring ways and means to answer these questions.

Another question that requires addressing in geo-visualization, particularly noted by ecologists, soil professionals, foresters and botanists, is whether or not landscapes rendered in visualizations represent the native vegetation, geology and soil types for a given geographic location. Often, interaction is associated with knowledge about the type of information being visualized. Diseased trees (Fig. 7), for example, could engage the curiosity of a pathologist. This aspatial information describes attributes and their associated values for soil, animals, plants, geology and water from a local geographic area. Spatial databases are, for example, constructed to include physical attributes including roads, rivers, buildings, pipelines and utilities. Ideally, visualizations would couple the spatial tables to the aspatial tables – which can be done by 'joining' the tables. But, in some cases visualization software include libraries of textures including vegetation, which may not have been developed from local vegetation. Needless to say, it can be an awakening experience when presenting visualizations for an area in South America, where the rendering includes vegetation native to the boreal forest of northern Canada!

Speed / Accuracy in Geo-Visualization

One way to render an image with cartographic accuracy while providing the rich, robustness of visualization is to use multiple perspectives. While three- and four-dimensional GIS have been developed to represent multidimensional geo-phenomena using geometry, the development of spatial multimedia and virtual reality systems has opened up new possibilities for multidimensional representation of a more direct nature (Camara and Raper, 1999).

An example of multi-representation can be seen using a satellite image of New York City, rendered in World Construction Set, which shows Manhattan Island in the center of the image (Fig. 8) and the camera viewpoint and the perspective image in the right.

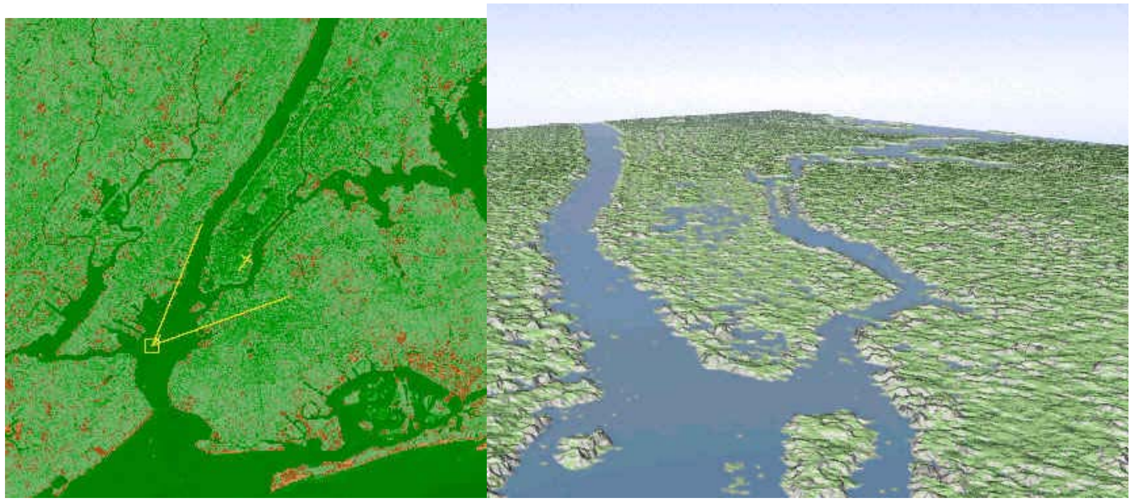


Fig 8. – Cartographic and Perspective Viewpoints of NYC – World Construction Set

In the cartographic (orthographic) perspective, scale can be assigned to the visualization and areal distances can be measured. In the right (perspective) image, the scale varies across the image from foreground to background and perhaps side to side - if the image is not ortho-rectified. As does detail. It is for this reason that GIS users and cartographers raise issues about scale and accuracy with respect to non-orthographic visual presentations. However, the dual representation provides the viewer with both a cartographic and perspective viewpoint. The Web3D organization is working on GeoVRML with a view to including scaleability, metadata, animation and other features into a new VRML standard that will meet the accuracy and cartographic issues of those involved in geo-visualization.

Dependent upon the sizes of the images being rendered, considerable processing capability is necessary for both speed of rendering and speed of movement. In some cases millions of polygons need to be rendered, quickly and accurately. One way to achieve these levels of efficiency is to utilize a CAVE environment. At the University of Alberta,

Fig. 9 – CAVE 3-D depiction running on a SGI Onyx super computer

a CAVE is in operation, which is capable of rendering 11 million polygons per second on a SGI ONYX-2 supercomputer (Fig. 9). In a CAVE environment, the viewer is surrounded by the rendering and interacts with the rendering by walking through the scene presented – which is stereoscopically reproduced. This does not, however, mean that a super computer is required to produce effective and interactive visualizations. Numerous manufacturers presently provide graphics accelerators that significantly increase graphics resolution and speed. The future of visualization and GIS will present many new discoveries in both hardware and software. Already, users of spatial products are exploring new applications to convey their thoughts and communicate their ideas. The GeoVISTA project at Penn State University is working on the rendering of images that indicate scale and errors associated with geo-visualization, taking into consideration cartographic factors.

Closely associated with these endeavors, are new hardware and developments to telecommunicate visualizations via the internet. Undoubtedly, future creative geo-visualization efforts will turn to training individuals capable of understanding and integrating numerous geo-technologies, necessitating a need for new curriculums. A need exists to educate people to extend visualization, push the envelope, and venture into new directions. Few, if any, current educational programs are focused on developing curriculums, which integrate geo-technologies and couple them to visualization.

Geo-Visualization into the Future

A few factors will converge in the near future which will set the stage, opening new possibilities, products and directions for GIS. Briefly, these are identified as follows:

- Costs of technology for producing very high quality visualizations will drop and visualization features will be extended in most software (not only GIS). All things will have a spatial context.

- Determine of volumes in GIS coupled to visualization will come to the desktop, much like having medical imaging capability on the home computer – provided through true 3D topologies and voxel applications.

- Consumers will become increasingly aware of cartographic representation and view visualizations more critically, demanding higher levels of accurate photo-realistic interaction.

- Applications will turn from presentation to involve human factors, such as perception and a clearer understanding of how people utilize graphics. This will open the door to artificial intelligence models tightly coupled to GIS.

- 4-D applications (3-D + Time) – will become grow, driven by the coupling of instrumentation and sensor technologies in real-time constantly updating spatial and aspatial data tables.

- GIS will shift from large-scale applications (i.e. > 1:10000) to increasingly involve small-scale (i.e. < 1:10000) visualizations and approach (1:1) in some cases.

- Sounds and scents will be coupled to Geo-Visualizations. Thereby increasing levels of interactivity.
- New professions will arise – Geo-Technology Specialist, Business Geo-Modeler, Geo-Human Communicator, Geo-Visualization Accuracy Technologist, Network Visualization Distributor, Geo-Visualization Translators, Geo-Visualization Animators etc.

The future of geo-visualization will be exciting as individuals explore information more fully, more quickly and with more realism. However, we will go far beyond simply watching pictures of spatial information flash before us, analyzed or not – artificial intelligence alternatives will be generated for landscapes, business, human movement and many more areas, in an integrated, holistic fashion. Now wouldn't it be interesting to be walking around a geo-hologram in the near future, smelling, touching and interacting with it – and perhaps having it talk back. Or, your computer indicating to you that, the spatial arrangement of furniture in your house is not oriented for optimal human utilization of space. Who knows, maybe that will lead to new ways of designing houses!

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