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3D Terrain Visualization of GIS Data for Analysis

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Abstract: ***3D terrain visualization of geographic information systems (GIS) data has become an important issue in recent years. The availability of 3D representation tools has increased the demand for 3D terrain visualization. The evaluation of remote sensing data from multiple sensors is complicated by different image scales and orientations. Thus a simultaneous visualization of the multi-sensor data is envisaged. For a spatial impression of the observed area the images are co-registered, projected onto a 3D terrain model and displayed stereoscopically. The presented 3D evaluation system allows the real-time navigation in the virtual landscape. The user is able to manipulate the 3D model by blending and mosaicking the images from different sensors in which geo-information system (GIS) offers the possibility to display GIS data.***

1. Introduction

Van Driel (1989) recognized that the advantage of 3D lies in the way we see the information. It is estimated that 50 percent of the brain's neurons are involved in vision. What's more, it is believed that 3D displays stimulate more neurons: involving a larger portion of the brain in the problem solving process. With 2D contour maps, for example, the mind must first build a conceptual model of the relief before any analysis can be made. Considering the cartographic complexity of some terrain, this can be a arduous task for even the most dextrous mind. 3D display, however, simulates spatial reality, thus allowing the viewer to more quickly recognize and understand changes in elevation.

Geographic Visualization depends on psychological cues to create a *natural* 3D scene on a 2D computer monitor. In a sense, visualization models are not photographs, but pictures or renditions. Hence, the process of generating a scene is termed rendering. To render the most realistic scene, the geographer might rely on such visual cues as simple perspective rules or the subtle change of color or texture with distance. Depth may also come from feature obstruction and overlap, or from the addition of atmospheric attenuation such as fog or haze. Often the clever use of lighting sources and clouds can heighten the relative distance within a scene. Finally, the generation of trees or even seasonal characteristics such as snow can artificially enhance the sense of reality. There are physiological cues, as well, such as accomodation, convergence, or the retinal disparity of a stereoscopic image. Whatever the combination, geographers should be careful not to abstract reality too much, consequently misleading the audience.

Still, due to time and sampling constraints, terrain simulation has become common practice in visualization. Instead of wasting time laboring over every detail, geographers employ computer algorithms that reasonably synthesize a terrain surface. Most terrain algorithms are based in **fractal geometry** which argues the concept of self similarity. Self similarity implies the invariance of spatial structures or features under changes of scale; that is, what appears at one scale repeats itself at another. Landscape form can be described by the fractal dimension of the surface. A fractal dimension is measured as a real number ranging between 2 for a perfectly smooth surface and 3 for an infinitely variable surface. Although self similarity does not occur in nature, a fractal dimension between 2.2 and 2.3 will produce a very realistic looking landscape.

Most GIS software is capable of handling topographic data, usually as a **digital elevation model** (DEM), and of generating isometric views and contour maps. Many products also integrate scene generation systems for the 3D visualization of data. Yet, although Z coordinates data is now easily recorded or readily available for surface features, this third dimensional aspect of a GIS dataset is generally disregarded. This makes little sense considering, for example, that in geological analysis, instead of struggling with different layers to identify the relationship between lithology and landforms, a geologic map can simply be draped over the topography. To be considered a 3D GIS, the system must be capable of handling data as more than a surface; it must handle data as an object.

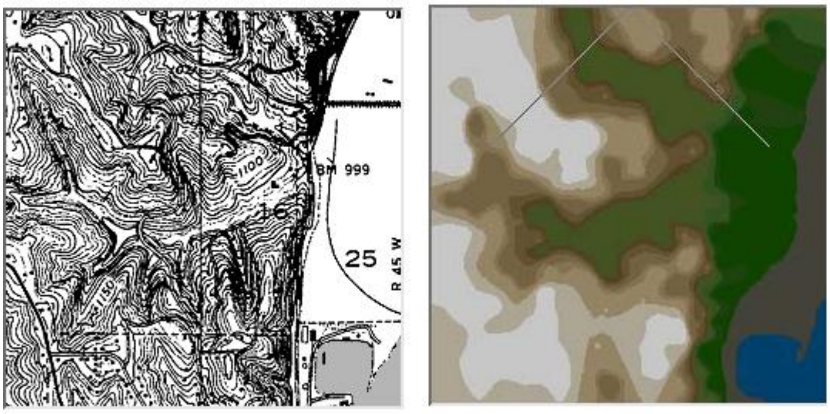
The significance of 3D

In comparison to the advancements in 3D visualization, relatively little has been accomplished in the realization of a practical 3D GIS. The obvious reason remains: the transition to 3D means an even greater diversity of object types and spatial relationships as well as very large data volumes. In a 2D GIS, a feature or phenomenon is represented as an area of grid cells or as an area within a polygon boundary. A 3D GIS, on the other hand, deals with volumes. Consider a cube. Instead of looking at just its faces, there must also be information about what lies inside the cube. 3D GIS require this information to be complete and continuous. Clearly, the data management task has increased by another power. More problematic, however, is the initial task of acquiring 3D data. In medical imaging this is not particularly difficult. But for geographers working at much greater scales, this can be an exercise in interpolation and spatial adjacency. The data acquisition problem is particularly acute for geologists who must overcome the limited availability of subsurface information.

Once the data is collected, a raster or vector 3D data structure must be chosen to describe geo-objects. Besides points and arcs, features can also be indexed as surfaces and bodies. Take the cube again, a simple example of a body, and drill an imaginary hole through it. Now, how do you describe this instantly more complex object?

Geographers have come up with a number of approaches to representing 3D geo-objects as volumes. Raster solutions subdivide the 3D *universe* into volume elements or **voxels**. This contrasts with the vector approach in which volume is determined by a feature's bounding surface. Whatever the structure, true 3D GIS analysis demands that feature points, arcs, surfaces, and bodies be manipulated and analyzed as discrete entities.

In the raster approach, voxels serve as the building blocks for geo-objects. There are three methods to store voxels. The simplest form of storage is as a **Binary raster**, where voxels are indexed as *on* or *off* depending on whether they make up a particular geo-object. Understandably, this approach often requires large amounts of available storage. Another alternative is indexing by **octree**, the 3D equivalent of the quadtree. In this technique, a volume of space is recursively divided into 8 parts until each part of the subdivision is homogeneous. The octree structure allows for efficient Boolean operations on geo-objects, but it is time-consuming to build. Lastly, **constructive solid geometry** (CSG), a common CAD/CAM solid modelling technique, combines the occurrences of 3D primitives--objects such as cubes, spheres, and cylinders--using geometrical transformations and regularized set operations into a binary tree.



A. Mile Section of Ponca Hills taken from USGS Quad Map

B. DEM created in Vista Pro

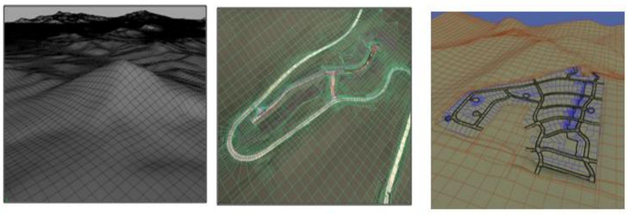
Figure 1: A section of a) Topographical map and b) DEM Creationof the same

Vector data models are more complex and, some would argue, more concrete. Mathematicians, with their theory of k**nots**, have tried to understand the complexities of embedding an arc in 3D space. What geographers should garner from their study is that this is no trivial task. In a topological approach, 3D boundary representations or iso-surfaces are defined for the indexing of geometrical data. **Boundary representations** (B-reps) describe the surface of a volume by the relationships between the faces, edges, and nodes which compose that volume. An appropriate geo-relational system then links these B-reps to attribute data. The topolical data structure, which makes 2D systems like Arc/INFO so good at analyzing spatial relationships, imposes a query model that inhibits interactivity.

Data Formats: In order to create 3D, all data which are georeferenced have their data stored in different formats: Elevation Raster (Arc Grid, DEM), RGB Raster (GeoTiff, Sid), Tin (Survey Contours), Shapefiles , CAD , Map 3D, Other (Polygon Mesh , DXF/DWG , Sketchup,Tree Surveys , TIN, Custom data entities)

Software: Softwares are available for creating 3D visualization. Some of them are Maya, 3D Studio Max, GIS (Arc Gis,Map 3D) etc. These are made for optimal image quality, flexibility, lighting and speed and for visual databases, it is slower less evolved 3D displays (Arc Scene, etc)

Advances Production: 3D Visualization is procedural in nature with automated tools † The Ortho Imagery is imported whereby linework from shapefile is added.† Creation of Roads (cut and fill), † Trees and buildings (blueprints, footprints) is added.† Road construction, linework, 3d surface etc is generated. This process take advantage of existing GIS data, For example: 3d lines from a Shapefile , draping lines over a DEM. In this stage convert DEMS to polygon mesh is done.



Creation of Polygons

Cut & Fill Process

Road Construction

Figure 2: 3D Creation Procedures

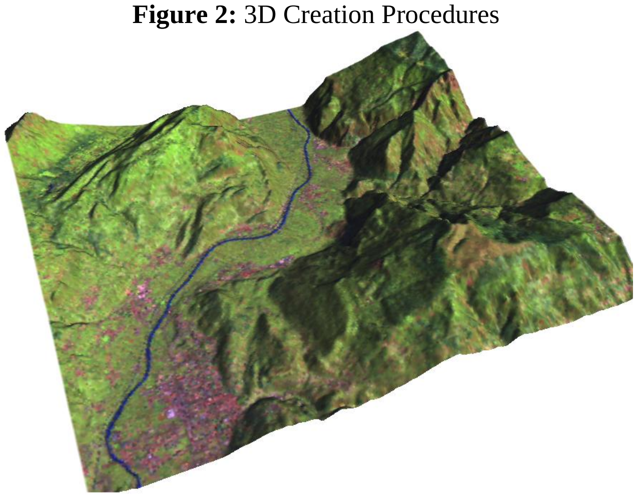


Figure 2: 3D Creation of a terrain

Open Source Tools

Some Open Source tools like GDAL/OGR translators, Quantum GIS/GRASS, Linux Based systems (Maya renderfarm, python scripts) etc can be used for 3D visualization creation.

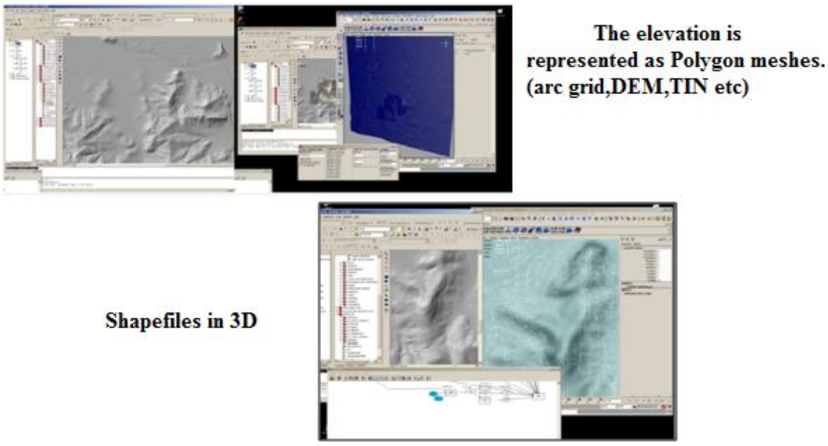


Figure 3: Tools for 3D Creation

3D Visualization

The entire process is object-oriented structuring. What this approach sacrifices in terms of spatial analysis, it makes up for in its ability to allow direct and continual access to attribute data. This is accomplished by linking feature attributes to structures designed for 3D graphical representation; hence, allowing the geographer to perform continuous mapping and querying in an interactive environment.

The true power of a 3D GIS, then, is the ability to communicate complex geographic phenomena. Besides showing change, the added dimensionality of a 3D GIS allows geographers to themselves in fence diagrams, isometric surfaces, multiple surfaces, stereo block diagrams, and geo-object cut-aways.

The 3D landscape model existing of the geocoded multisensor images and the digital terrain model is visualized stereoscopically and in real-time to the human interpreter. The 3D evaluation system should provide the following functionalities: a) navigation in the virtual landscape, b) separate activation and deactivation of the sensor data, c) blending of the different images, d) interactive creation of image mosaics, e)realization of simple measurement tasks, e.g. distances, f) online access to GIS data. The features mentioned above demand for a particular user interface on the one hand and a special model representation form on the other hand. Furthermore the system has to provide an interface to the GIS database.

Interface to Geo-information System:

For the evaluation of the remote sensing data it is useful to integrate data from a geo-information system (GIS). For example the user might visualize the road net of a region of interest to explain the linear structures in a SAR image. The 3D visualization system provides an online interface to the used GIS SICAD/open giving access to the GIS data during evaluation. After selecting an object class in a region, objects like roads, forests, bridges etc are identified. The arbitrarily formed region is transformed in a rectangle defined by the bounding box. The given object class is translated in numerical codes of the German ATKIS. The data returned from the GIS database is gathered and the geometrical information is extracted. The visualization system can only process regions approximated by a triangle mesh, but streets for example are modeled in the GIS by their central axes. Thus all linear objects are transformed in stripes using the information about their width. The GIS data is transferred to the visualization system which triangulates each region and includes it in the scene graph. The GIS information represents a separate layer of the model which can be manipulated and deactivated in the same way as all other layers

2. Conclusion

Compared with 2D GIS, 3D GIS decibels the objective world in a more realistic way, which shows geospatial phenomena to users by 3D modeling technology. It not only expresses the relationships between spatial objects in the plane but also describes and expresses the vertical relationship between them. In addition, carrying out 3D spatial analysis for spatial objects is the unique functions of 3D GIS (Tan, 2003). With the development and application of computer hardware and software as well as 3D GIS technology, if integrate the real estate mass appraisal model with 3D GIS, on the one hand make full use of 3D GIS spatial data management capabilities, 3D spatial visualization skills and 3D spatial analysis capabilities, in the other using the assessment model for the real estate mass appraisal, that will undoubtedly have a strong advantage. A system for the interactive 3D evaluation of remote sensing data from multiple sensors was presented. The images to be visualized are geocoded and projected onto a 3D terrain model. The textured 3D landscape model is visualized stereoscopically and in real-time to the human interpreter. An optimized representation form of the layered 3D model allows the manipulation of the multiple textures via the graphical user interface the textures can be exchanged and blended. The human interpreter has the possibility to mark arbitrary regions interactively. Hence he can create image mosaics to combine the multi-sensor data. An online interface to a geo-information system allows the visualization of GIS data for a region of his interest.

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