State-of-the-art 3D GIS: System Development Perspectives

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Abstract

Since the mid-1990's, researches on 3D GIS have been regarded as one of main issues both in the academic sites and commercial vendors; recently, some prototyped systems or the first versioned software systems of commercial basis are being reported and released. Unlike conventional 2D GIS, which consists in intelligent structured GIS or desktop GIS, every 3D GIS has its own distinguished features according to data structure-supporting capability, GIS-styled functionality, external database accessibility, interfacing extents with 2D GIS, 3D visualization/texture mapping ability, and so forth. In this study, technical aspects related to system development, SERI-Web3D GIS ver. 1.2, are explained. Main features in this revised 3D GIS can be summarized: 2-tier system model(client-server), VGFF(Virtual GIS File Format), internal GIS import, Feature manager(zoning, layering, visualization evironment), Scene manager(manage 3D geographic world), Scene editor, Spatial analyzer(Intersect, Buffering, Network analysis), VRML exporter. While, most other 3D GISes or cartographic mapping systems may be categorized into 3D visualization systems handling terrain height-field processing, 2D GIS extension modules, or 3D geometric feature generation system using orthophoto image; actually, these are eventually considered as several parts of "real 3D GIS". As well as these things, other components, especially web-based 3D GIS, are being implemented in this study: Surface/feature integration, Java/VRML linkage, Mesh/Grid problem, LOD(Level of Detail)/Tiling, Public access security problem, 3-tier architecture extension, Surface handling strategy for VRML.

1 INTRODUCTION

To visualize the environment 3-dimensionally has been one of the main issues in GIS fields, because 3D visualization of our environment can simulate spatial reality, thus make viewer recognize and understand more quickly, and enhance the decision-making ability[1].

Todays, simulating terrain 3-dimensionally is one of the main features in commercial or non-commercial 3D GIS software systems. Those systems having strength on surface visualization are ERDAS Imagine and ArcView 3D Analyst. Some efficient surface data handling scheme such as Progressive Mesh or Multiresolution Analysis is intoduced[2][3]. These techniques are mainly for the efficiency in surface data compression, simplification, and transmission.

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. There are some approaches for structuring 3D GIS; Raster approach in which voxels serve as the building blocks for geo-objects, vector data models supporting topological data structure, and object-oriented structuring enabling attribute data access and continuous mapping and querying[1]. Based on one of these structures, 3D GIS should handle geographical feature data supporting query processing, spatial analysis in addition to dynamic user interaction.

Since the mid 1990s, 3D GIS on World Wide Web(WWW)[2] has been regarded as one of promising alternatives in the GIS field mainly due to cost-effectiveness and wide accessibility. In this newly emerging approach, Virtual Reality Modeling Language(VRML)[4] shows several linked aspects with 3D GIS under

Internet environment[5]. Actually, there are several attempts to use VRML for cartographic presentations and modeling; however, it was confined to displaying dynamically pre-formatted VRML files by other authoring tools in a certain VRML browser. Accordingly, they are not, in some extents, satisfied with fundamentals or key components of GIS: manipulation of real-coordinate spatial data, GIS-type file conversion or transformation, and spatial analysis and so forth. But the linkage between Java and VRML provides another way to Web-based 3D GIS[6].

There are some intrinsic difficulties to present georeferenced data in VRML regarding coordinate systems, time referencing, terrain representation, level-of-detail(LOD), resolution and accuracy, and data interchange. With these problems, the GeoVRML Working group, one of the official working group of the VRML Consortium, are acting to propose improvements or extensions to the VRML standards necessary to generate, display and exchange georeferenced data[7].

2 SYSTEM ARCHITECTURE

To design and implement web-based 3D GIS, the strategic linkage of Java and VRML is regarded, and the system has feature-based or object-oriented architecture. All important features such as buildings, roads, streams are managed in such a way that their spatial characteristics can be analyzed and displayed in conjunction with digital terrain model. Here, surface is also treated as a geo-object.

The overall system architecture is shown in Fig. 1. 3D geo-objects stored in Virtual GIS File Format(VGFF) files are imported via *Feature manager* and *Environment manager* into *Scene manager.* Zoning and layering is controlled by *Feature manager*. The *Environment manager* set the virtual environments such as viewpoint, background, light condition, viewer navigation condition, etc. Scene manager is a fundamental module in this system managing the 3D geographic world by controlling the scene graph. Some spatial analyses are performed by *Spatial analyzer* module. Editing on a geo-object, such as insertion and deletion is performed by Scene editor, and the result of edition effects the scene graph. Thus, the changed geographic world and the result of spatial analysis can be exported as VRML file format through *VRML exporter*, and then be utillized for other system.

2.1 *VGFF*

There are several file formats for conventional 2D GIS. But there is few file format available for 3D GIS. One of the most frequently used file format to present 3D vector data is the DXF(Drawing Interchange Format). However, with this format devised originally for CAD, is it difficult to present informations for 3D GIS, such as aspatial attributes, virtual environment-related parameters(viewpoint, background, light, etc.), multimedia information, terrain information. For these reasons, we devised a file format called VGFF for being used by this web-based 3D GIS. VGFF is a line-oriented ASCII file format similar to DXF and now on its beta version. It consists of two sections, *head section* and *body section.* The body section is composed of five sub-sections; viewpoint feature section, light feature section, background feature section, object feature section, and analysis feature section. Here, the object feature section contains informations for aspatial attributes of feature, appearance and geometry of geo-object, and multimedia linkage information. Analysis feature is for the objects created as the result of spatial analysis such as 3-dimensional intersection and buffering. More revision on this file format is needed, especially about the file compression, macro support, and refinements and compaction on each sub-sections.

2.2 *Feature manager*

Feature manager performs zoning and layering. Zoning, or vertical clipping is done through 3-dimensional spatial index. Layering is performed by selecting feature which will be loaded from file or database.

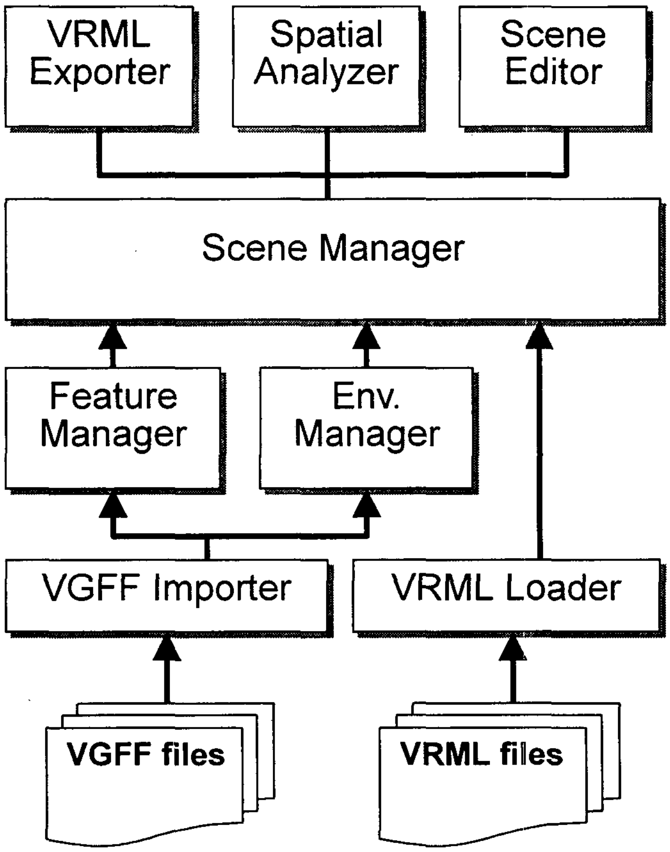


Figure 1. Overall system architecture.

2.3 *Environment manager*

To make the 3D GIS world more realistic and enhance the spatial cognition, Virtual Reality(VR) technology can be utilized. Some visual interfaces such as Head-Mounted Display(HMD) or Cave Automatic Virtual Environment(CAVE) can provide vivid visualization. It depends on psychological cues to create a realistic 3D scene on a 2D computer screen. Those visual cue depends on perspective rules or the change of color or texture with distance[1]. VRML supports virtual reality by providing capabilities such as control over background, light condition, viewpoint, sound, color, texture, and various navigation options. These various conditions for a scene or 3D GIS world is controlled by Environment manager module.

2.4 *Scene manager*

Each feature contains information on aspatial attributes, multimedia, and geometry of geo-object. Especially, the geo-objects are linked hierarchically into tree like scene graph. This scene graph is intrepreted by VRML browser and visualized as 3D geographical world. Any kind of user interaction such as select, insert, remove, or spatial analysis can change the scene graph, and then it's being reflected to VRML scene. The creation and modification of scene graph is performed by Scene manager in addition to the capability to interface with user and VRML browser.

2.5 *Scene editor*

The 3D geographic world or scene need to be editable. Inserting, deleting, and modifying on geo-objects change the scene graph and will be reflected to VRML browser. Deletion on geo-objects is shown in Fig. 2(a) and Fig. 2(b).

2.6 *Spatial analyzer*

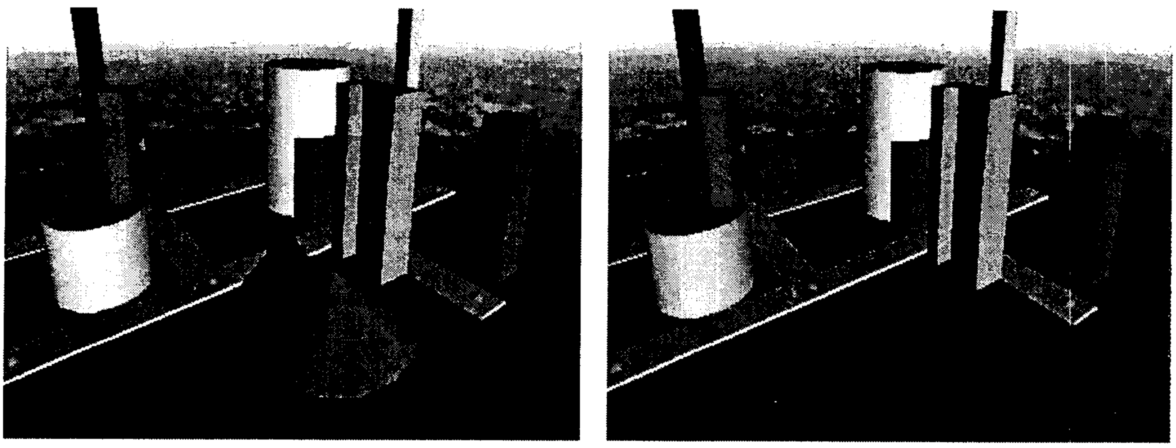
Functionalities for 3D geographical analysis are those of the most important parts in 3D GIS. 3D geographical analysis can be categorized by their functionality: geometric analysis, spatio-relational analysis, geometry-generating analysis. Geometric analysis is performed on one geographic object, for example, calculating volume and surface area of an object. Spatio-relational analysis is performed on two objects to find the relationship of two objects in 3- dimensional space. There are analyses such as enclose, meets, and nearest. Geometry-generating analysis is performed on one or two objects and produces at least one object as a result of the analysis. In this analysis, are there 3-dimensional buffering, intersection, merge.

The design and implementation of the operators for these 3-dimensional geographical analysis are so closely related to the modeling scheme of geographic objects besides the complex computational geometry algorithm itself. The more amount of data is used for modeling an object, the deeper level-of-detail can be obtained and the reality increases. But the level of detail should be traded off with the availability in managing the geographic vector data and transmission efficiency in web-based application. We used rather simple modeling scheme for 3-dimensional geographic objects using some simple primitive types such as box, cone, cylinder, sphere, and some more general types such as extrusion and wirefram-like types.

The spatial operators implemented in this system is based on this simple modeling strategy but can be utilized for cost-effective 3D analysis. Examples on this operators including distance and near analysis. For more quantitative spatial analysis such as intersection and 3D buffering, wireframe-like modeling of geographical object is required in addition to the sophisticated computational geometry algorithm. It may be preferable to apply both simple and cost-effective qualitative analysis and complex and costly quantitative analysis method, in accordance with the LOD scheme of the 3D GIS. Network analysis finding shortest path is simulated as car navigation in 3D geographic scene, and shown in Fig. 3.

2.7 *VRML exporter*

The structure of scene graph used in this system is similar to that of VRML. So, the geographic world as it seen from VRML browser can be output to VRML file format. VRML does not support the GIS functionality, so it loses informations on aspatial attributes and topographic informations.



(a) (b)

Figure 2. Editing on geographical world. (a). 3D geographic scene composed of several geo-objects. (b). After deleting some geo-objects(cones, here).

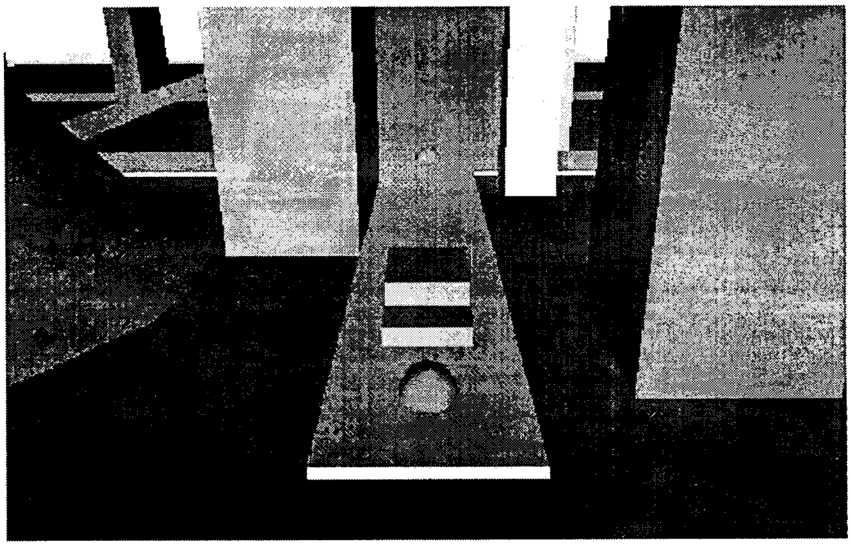


Figure 3. Network analysis finding shortest-path is simulated as car navigation in 3D geographic world.

3 CONCLUSIONS

We looked briefly at the web-based 3D GIS from the system development perspectives. 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 proposed system is based on object-oriented structure and implemented using visualization capability of VRML linked to Java. Some analytical functionalities such as 3D buffering, intersection, near can be performed on geo-objects modeled according to the abstraction level. The architecture of this system can be used well for the cost-effective, web-based, analytical 3D GIS.

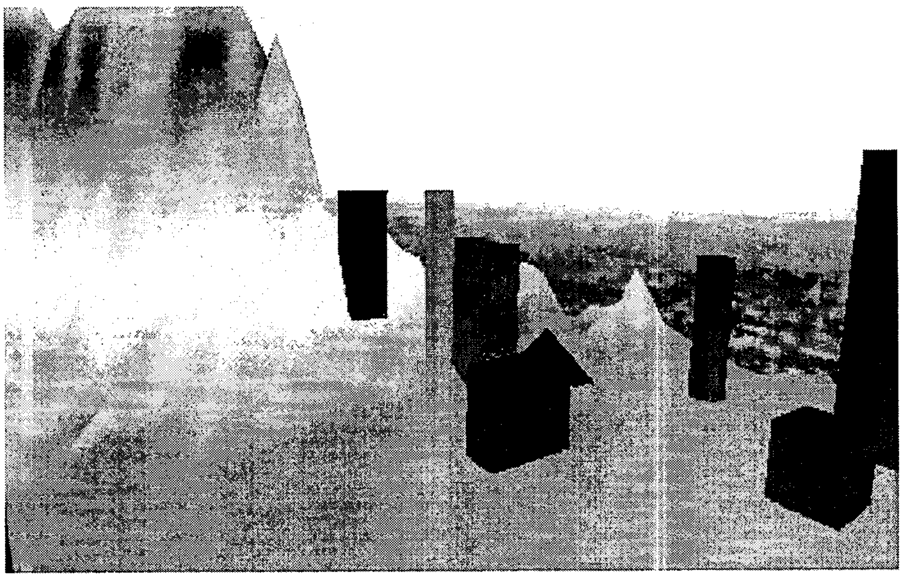


Figure 4. Geo-objects managed in the linkage with digital terrain data.

4 FUTURE WORKS

The level of abstraction on geographic world should be traded off with reality. To enhance reality, more complex geometric shape, realistic true color and photographic texture need to be supported. But, those are costly consumming transmission time and rendering time. In addition to hardware development, systematic support to these enhanced (virtual)reality need to be provided. But this should go well with other parts of system architecture not to make the system to slow to run real time via network. Geo-objects should be managed with the linkage to terrain data(see Fig. 4). And the way to handle surface data via network is also one of the issues need to be studied on. The effective way of acquisition and utilization of 3D data also should be studied more.

References

[1] Swanson, J., "The Three Dimensional Visualization & Analysis of Geographic Data", http://maps.unomaha.edu/Peterson/gis/Final_Projects/1996/Swanson/GIS_Paper.html

[2] Hoppe, H., "Progressive meshes", Computer Graphics(SIGGRAPH '97 Proceedings), 1996, 99-108

[3] Eck, M., DeRose, T., Duchamp, T., Hoppe, H., Lounsbery, M., and Stuetzle, W., "Multiresolution analysis of arbitrary meshes", Computer Graphics(SIGGRAPH '95 Proceedings), 1995, 173-182

[4] VRML, The Virtual Reality Modeling Language(VRML) 2.0 Specification, http://vrml.sgi.com/moving-worlds/spec/part1, 1996.

[5] Fairbairn, D., The use of vrml for cartographic presentation. *Computers & Geosciences* 23(4), 475-481, 1997.

[6] Kim, K-H., Lee, K., Lee, H. G., Ha, Y-L., "Virtual grographic world: the web-based 3D GIS", GIS technologies and their environmental applications, 343-352.

[7] GeoVRML Working Group, http://www.vrml.org/WorkingGroups/