3D Symbolization and Multi-Scale Representation on Geo-Information

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Abstract. Three dimensional GIS has become a symbol and an important means of expression of geographical factors. This paper analyzes the present situation of 3D visualization technology, discusses several main ways to study the main 3D geographic information visualization problems, and expounds the basic principle of design of the multi-scale symbol and multi-scale symbols show experiment. Results show that based on multi-scale technology of 3D symbols, 3D GIS has good display effect and map efficiency.

Keywords: 3D modeling, 3D multi-scale symbolic model, 3D visualization

1. Introduction

In recent years, with the development of 3D GIS (Geographical Information System) software like Google Earth, Skyline, NASA World Wind, Virtual Earth, 3D representation of geographic information is increasingly becoming a kind of trend. Compared to traditional 2D representation, geographic information can be expressed in a more intuitive and effective manner with architectural models being modeled and visualized in a virtual 3D environment. 3D representation and visualization provides better visual effect and vivid urban geographic information, and thus plays an important role in people's perceptions of their environment. Meanwhile, large-scale 3D models with regional characteristics have become important form of geographic data beyond conventional 2D geospatial data, like multi-resolution remote sensing images and vector data (Zhu, Gao, Wei, Huang, 2003). In addition to the 3D analysis of spatial objects, the 3D spatial operation is also unique features of 3D GIS. 3D GIS has the unique ability to manage complex spatial objects and spatial analysis capabilities. The figure1 shows the real world, expressed by 2D GIS and 3D GIS. It displays the difference between

3D GIS and 2D GIS in visualization (Wei, 2006). 2D digital maps, remote sensing image and DEM are overlaid to construct 3D landscape models. Although it can represent the accidents of the ground, it's the visual model essentially. But the ultimate reason is：for a point (x, y) of plane, its third dimension is only z value of the height information. This brings about more value cannot be deal with, which can only be considered as a 2.5-dimensional object (Chen, 2002).

Figure1. Representation of real world, 2D GIS and 3D GIS

2. How Visualization Should Be?

3D GIS integrates geography, geometry, computer science, CAD technology, remote sensing, GPS technology, Internet, multimedia technology and virtual reality technology, using the computer graphics and database technology to acquire, store, edit, display, convert, analyze and output geography graphs and attribute data, and illustrates these information according to need of the user to facilitate analysis and decision making. 3D GIS has made great progress in geology and mineral resources, land information, pipeline into diagrams, 3D simulation etc.

In visualization, the main works are on the terrain surface reconstruction, housing construction and other aspects of geometric modeling. Technical difficulties are mainly large-scale scenes of the show, fine depiction of the scene, and the indoor fine scene modeling and rendering (shown as figure2-5).

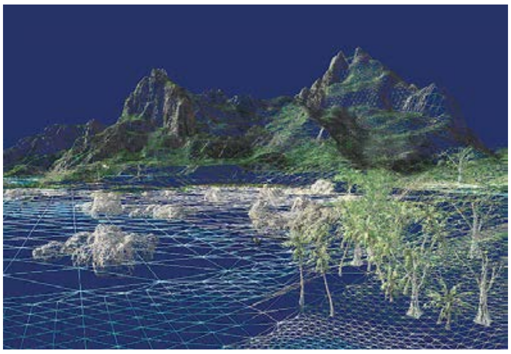

Figure2. 3D scene illustrated by grid

Figure3. Demonstration of large-scale scene

Figure4. Illustration of the fine scene

Figure5. Illustration of the fine scene (indoor)

Large-scale 3D scenes and interactive rendering fine scene in scientific visualization, flight simulation, 3D GIS, virtual reality and digital entertainment system have their wide applications. Considering the large-scale scene, terrain model data and the corresponding texture data are mass data (with 1 meter resolution IKNOS satellite images as an example, the image data quantity covering the whole world IKNOS is as high as 1500TB). Fine detailed scene demands that the amount of data (triangle face several) is no less than large-scale scene. Because of the limit of computer hardware, which is far exceeding the real-time processing ability of computer system, fine detailed scene may not be directly drawn, thus we must improve data scheduling algorithm and terrain rendering strategy. Many domestic scholars in 3D terrain real-time rendering make significant research work and have achieved some results. In order to solve the display quality and display speed, the conflict between the current widespread use and the Level of Detail technology (Level of Detail, LOD), based on the algorithm (Out-of-Core), they combine scene cuts technology to simplify the whole scene complexity, reduce the amount of data in drawing triangle.

The most difficult part of the visualization problem is the conflicts between limited processing capacity of computer and massive volume of model data, particularly in the procedure of model rendering (Sui, 2010). Taking the 3D modeling of a city for example, using traditional 3D modeling method, suppose there are 100 000 buildings to model in the urban area and the average size of model data for each building is roughly 10M. So the total data volume of building models in the city could reach a TB level. However, the capacity of ordinary computer memory is only in the GB scale. Based on this concern, the authors propose the scheduling technology for large-scale 3D objects models in aspects of model loading and rendering.

However, in 3D virtual environment, due to the difference between data organization and manners of human computer interaction (HCI), we need to apply a new standardized method of modeling and scheduling for 3D models. At present, there is no such a uniform method as the constructing specification or standard for the modeling of 3D objects. Existing approaches are insufficient and inefficient in the scheduling of large-scale building models, resulting in poor performance or large memory occupancy. In response to such questions, the authors propose a new method for the construction of 3D object models. For the 3D modeling of objects in scenes of large scale, the proposed methods can not only remarkably reduce the complexity and amount of model data, but can also improve the reusability and factuality of models. Concerning the scheduling of large-scale models, Level-of-detail algorithms provide efficient rendering for large, complex 3D terrain data (Duchaineau et al. 1997) and geo-spatial objects (Davis et al. 1999; Willmott et al. 2001). (As shown in figure 6-7) Numerous optimizations for virtual environments have been developed, such as discrete and continuous multi-resolution representations of geometric objects, view-frustum and occlusion culling, imposter techniques (Schaufler, 1998), scene graph optimizations, and recently out-of-core visualization techniques, which directly render large amounts of data from external memory in real-time (J. Döllner, H. Buchholz, 2005).

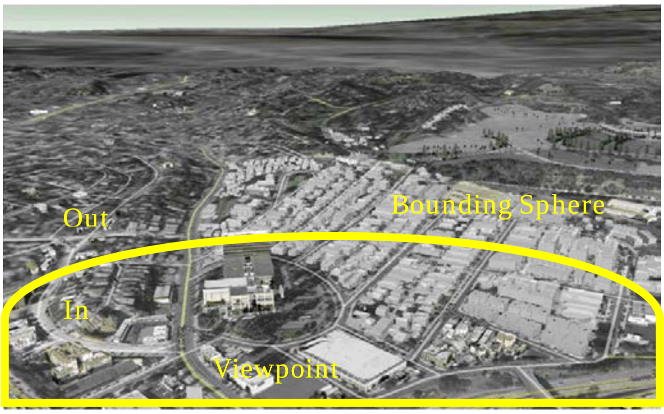

Figure6. 3D scene LOD displays based on the viewpoint

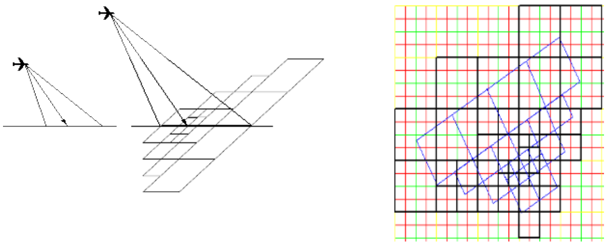

Figure7. LOD dynamic scheduling based on the viewpoint

3. Vector Data Visualization in 3D Virtual Environment

In the existing 3D GIS, the vector data visualization technology has not yet been widely introduced. Vector data on the 3D terrain visualization techniques can be divided into two categories: texture-based visualization technology and visualization techniques based on geometry. Texture-based methods will vector information grid optimization, and as texture mapped to terrain model. Vector data grid of the pretreatment stage finish, and will not affect real-time rendering efficiency. But for large-scale terrain scene, however, the operating expenses are considerable. And grid of operating reduces the accuracy of vector data, and can easily be misinterpreted when viewpoint close to ground. Vector data based on geometric approach are generated under the 3D geometric primitives and these primitives are added to the terrain surface. Since most of LOD terrain models are multi-resolution model, the grid moves with the view changes, in order to ensure the vector element is always attached to the surface, vector element must also be updated in real time, thus real-time systems will be affected. In addition, the vector element based on the geometric approach will bring conflict of Z buffer (Z-Buffer Fighting), namely when the geometric primitives (points, lines, polygons) accurately attached to the surface, the surface of the drawing and vector drawing will produce conflict, scene flicker.

Kersting put forward a balance between accuracy and efficiency of the 3D virtual environment vector data visualization methods. This algorithm is based on the improvement of texture of vector data visualization method. For the inherent defect of texture-based method, Kersting organized vector data with the scene graph, real-time texture pyramid (On-Demand Texture Pyramid) as a multi-resolution texture. The algorithm supports the dynamic update vector data. Compared with the traditional method based on texture, Kersting's method has greatly improved whether on efficiency or accuracy. For line in the traditional GIS vector data, Wartell proposed triangular cuts directed acyclic graph (the triangle clipping DAG) data structure that the center line and the global 3D terrain rendering algorithm of vector data. It belongs to geometric method. The disadvantage of this method is that it costs big and need larger pretreatment of storage space.

Based on block (which - based) LOD terrain, Agrawal realized vector data multi resolution modeling and rendering. It belongs to geometric method. In this method, combined with the finest terrain model grid of the original vector data, the unit will block the terrain raster data segment, and finally the raster data to vector information contained in the block stored in the same file. In the drawing stage, vector points are calculated by interpolation under the current LOD level. This method still exist big shortcomings of pretreatment time consumption and large memory occupancy. Schneider cleverly applies template volume shadow (stencil shadow volume) to real-time rendering of 3D vector. This algorithm calculates the vector data corresponding to shadow body, and then rendered to the stencil buffer shadow body which produces vector mask, mask for a scene to draw the final realization of the vector data visualization. This algorithm working in screen space can be accurate to a single pixel, and the texture-based method can avoid aliasing caused problems. The complexity of the algorithm has nothing to do with the terrain model complexity, rendering efficiency only depends on the complexity of vector data, and therefore, when the vector data overload, the performance of the system will be affected.

The construction of 3D environment requires a lot of 3D object model. There are a lot of ways to create 3D models, and a variety of professional software which can construct 3D model, such as 3DSMAX, AutoCAD, Google Sketch Up, Multigen Creator, and so on. By Using these software we can create models with very high precision, but there are still some problems in fast construction of large scale 3D environment scene. Firstly, it costs a lot to construct a model. It will take a lot of effort and high cost to create the city's large number of building models, so we only use the high precision model in important areas. Secondly, computer rendering model takes a lot of computation. Up to now, it is still difficult to improve the model and rendering efficiency at the same time. Thirdly, we have to create different models for different buildings with the help of professional software, but we can't quickly create all the models. Finally, if we want to put the model to the correct position, the bottom contour and object's vector polygon of the 3D model must be matched correctly (Y. Gan. J.N. Weng, 2010).

An increasing number of virtual 3D models are systematically built based on a wide range of techniques for acquisition, classification, and analysis of urban data derived from, for example, laser scans, aerial photography, and cadaster information bases (Hu et al. 2003; Ribarsky 1999; Förstner 1999). For many applications, however, the virtual-reality paradigm is neither cognitively adequate nor adequate with respect to the task to be supported by interactive visualizations (J. Döllner, H. Buchholz, 2005). Photorealistic display implies a number of limitations with respect to virtual 3D environment models:

□1) The larger the virtual 3D environment model is, the higher the costs for data acquisition is. In most cases, required data will not be available for a whole 3D environment model. As a consequence, the images are faced by a breach of graphics style.

□2) To integrate thematic information in photorealistic depictions, the information needs to be visually combined with the virtual 3D environment model, which turns out to be difficult because textured façades, roofs, and road systems dominate the image space.

□3) To visualize complex information, photorealistic details increasingly interfere with a growing number of information layers.

□4) To express objects of environment models in different states, e.g., existing, removed, and planned buildings, photorealism does not offer a broad range of graphics styles to communicate these variations such as by sketchy and outlined drawings.

□5) To generate compact depictions for displays with minimal capacities, e.g., on mobile devices, photorealism frequently fails due to the visual complexity inherent to photorealistic images. For example, a scaled-down version of a digital photography has a drastically lower information level compared to a scaled-down version of a hand-drawn sketch of the same scenery.

In a lot of buildings, how to identify specific goals, such as police stations, schools, etc. A large number of geographical objects show that if every true picture of the amount of data is difficult to imagine, then it is not necessary. Will you observe every wall of the building? Will you be asked to model every tree according to its original appearance? It's evident that many geographical objects is not necessary to model separately, instead of 3D symbols model. Although it is unified to describe part of 3D terrain goals, under the environment of the elements of the recognition, it is helpful for information acquisition of users. Since the data exists in the cache, reducing disk access can improve the display and the processing speed of the system. It merges the similar, reduces the amount of the rendering data, improves display efficiency, and also enhances the scope and capacity of the system's display.

With the advent of symbolic 3D rendering, a repertoire of illustrative, expressive, and artistic graphics techniques becomes viable to developers and designers of 3D geo-virtual environments. As Durand (2002) points out, non-photorealistic computer graphics offers extensive control over expressivity, clarity, and aesthetic, thereby the resulting pictures "can be more effective at conveying information, more expressive or more beautiful".

The traditional maps are generated on reality and processed after the achievements, this is self-evident. Its classification, schema, symbols such as grading, are all produced by predecessors in a lot of practice experience without exception, and this is a kind of summary. Entered the information age, the computer plays a very major role. Doesn't information need to be carried on the processing? On the contrary, the information age, that is, the era of explosion of information, how can we find, or recognize what I want in such a large amount of information. Therefore, to a variety of users, the content of each is different, and in their eyes, whether traditional map legacy experience is useless? Although the technical means to make the performance are different, the processing of the information available to users for a better reading (that is cognitive) will not change. Just think, in a lot of real buildings, how do you know which is the school, which is the fire station, which is the police? Of course, labels can do, but whether it also affects reading by too much tagging? Obviously, symbolization is a way.

Those who have been pursuing photorealistic won't agree, but is it the effect of everything? Moreover, photorealistic are often different from the reality. The former deliberately processes for effect, using many techniques, but the "real" is usually "ugly". This can often be seen when the real estate developers make 3D scene.

In order to obtain information, the users will not just look at the scenery, the symbols of vitality. Actually, the symbol is ever-present. You will deliberately makes one desultorily trees looks neat some, in order to make a picturesque village. This means that the abstract purpose differs. But 3D scene is not only effect, but also should be first based on effect to provide information. This is the ultimate objective of cartographer.

To cope with complex geometry, detail reduction is used both at the technical level by multi resolution modeling and level-of-detail techniques, and at the semantic level by generalizing buildings to quarters if their distance to the camera exceeds a given threshold.

In practice, high quality, precise models of large areas are hardly available due to time and costs efforts involved. For this reason, the symbolic 3D rendering technique should allow for generating compelling depictions of most buildings geometry in an automated way (J. Döllner, H. Buchholz, 2005).

4. Basic Principle of Multi-Scale Symbol Design

With the extensive application of 3D GIS, the conflict between more realistic scenarios with high performance requirements of complex systems and limited hardware and software performance, the conflict between the human, material and other costs are increasingly prominent. Clark's level of details (LOD) technology is one of the most common methods to resolve this contradiction. In the field of cartography, data on different scales using different techniques are often independent acquisition and storage, not just high-precision data is simplified by low precision data. Multi-scale 3D symbol design mainly realize through LOD model. LOD model refers to the same scene or objects in the scene, using different ways of detailed descriptions to get a group of model for drawing choosing to use. The higher the level of detail of objects is, the more sophisticated the description is, and the greater the amount of data is. The lower the level of detail of objects is, the simpler the description is, and the smaller the amount of data is. As shown in figure 8:

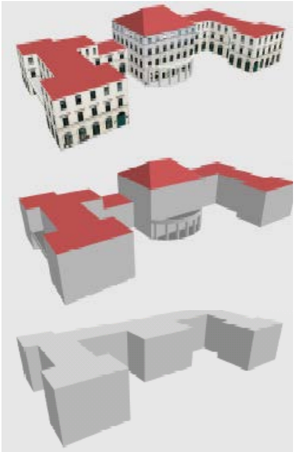

Figure8. Building LOD model

The geometric simplification of complex 3D objects has been a topic in various fields of research (M. Kada, 2005). Building geometry as the most important category of data can be generally classified into five quality levels (Altmeier and Kolbe 2003):

□Level 0: 2D ground plans with included landmark buildings;

□Level 1: Cubature objects, typically derived by extruding 2D ground plans to an average or known height;

□Level 2: 3D objects, with an approximated outer geometry including roofs, terraces, chimneys, etc.;

□Level 3: Architectural 3D models including detailed façade designs and exact geometry;

□Level 4: Architectural 3D models as in level 3 with additional interior design.

In particular, they facilitate visual abstraction as a primary technique to effectively communicate complex spatial information and associated thematic information. LOD Selection Criteria (A. Çöltekin, 2005): The following are listed as LOD selection factors (compiled from Reddy 1997, Constantinescu, 2001, Luebke et al 2003):

- Distance
- Size
- Priority
- Hysteresis
- Environments Conditions
- Perceptual factors

- Eccentricity
- Velocity
- Depth of field

Based on the 3D symbols LOD model realized the multi-scale design. LOD models are divided into static and dynamic. Compared with dynamic models, static LOD model stores multiple copies of the original model, each corresponding to a particular copy of the resolution [14-16]. All copies formed a pyramid structure. The model has the advantage of having online generation model, the visual speed and easy program realization.

Multi-scale symbols show callbacks, using distance rule to judge, handled by the scene manager and symbols according to the distance between observation point to select the appropriate LOD models. With the scale (the observer's point of view) changes to determine which LOD model should be used to represent the 3D symbols.

In Windows environment, the example of 3D geographic information symbolic display are finished by using VC programming language combined with OpenGL graphics library. From experiments, it proves that 3D symbols have a very good visual effect on presentation of geographical features, and it plays a significant role in enhancing map expression and the user's cognitive level of geographic information. Figures 9~10 show the effects of related experiments.

Figure9. Symbols display in the terrain scene

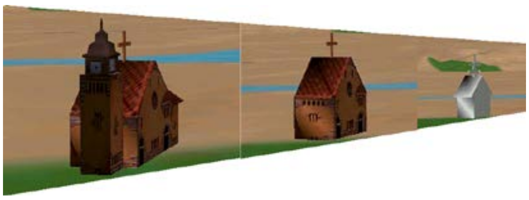

Figure10. Symbols display in the terrain scene

5. Conclusion

Vector data visualization technology in 3D virtual environment is still not developed. There are two problems about visualization methods based on geometry: First, the conflict Z buffer, and second, to draw vector LOD must changes with LOD changes of terrain. Two sets of LOD mutual constraint and transform may cause a large decrease system performance. Texture-based approach will not lead to Z cache conflict, but its precision is limited, prone to aliasing. And this method is essentially a 2D methods which cannot create 3D model vector. The development of LOD symbol, can improve the rendering efficiency, but cannot avoid the configuration of the terrain LOD resulting in reduced performance. This accurately indicate that the 3D virtual environment needs to solve the vector data organization optimization of the vector information, vector of 3D modeling, vector and 3D virtual environment accurately match. These are also the current needs and difficulties of long-term research focus.

Acknowledgment

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References

Y.J. Wei (2006), Research on management of 3DGIS data organization and representation of 3D symbol. Zhengzhou: Institute of Surverying and Mapping, University of Information Engineering, 2006.

Q. Zhu, Y. Gao, Y. Wei, D. Huang(2003), "Design of 3D Models for 3D GIS," Geomatics and Information Science of Wuhan University. vol. 28(3), pp. 283-287, 2003.

J. Chen(2002). "Developing Dynamic and Multi-dimensional Geo-Spatial Data Framework". GEO-INFORMATIONS SCIENCE. Vol.(1),pp.7-13,March,2002

P. Ortiz, H. Sánchez (2005). VIRTUAL CITY MODELS COMBINING CARTOGRAPHY AND PHOTOREALISTIC TEXTURE MAPPED RANGE DATA. The International Cartographic Conference, 2005, July 9-16, Coruna, Spain.

X.Y. Jin, Jinnong Weng(2010). Research and Application on 2D and 3D Interactively Automatic Construction Technology of 3D Model. The 18th International Conference on Geoinformatics 2010,June 18-20, Beijing, China.

Z.W. Sui(2010). Constructing Rules and Scheduling Technology for 3D Building Models. The 18th International Conference on Geoinformatics 2010,June 18-20, Beijing, China.

J. Döllner, H. Buchholz(2005). EXPRESSIVE VIRTUAL 3D CITY MODELS. The International Cartographic Conference,2005,July 9-16, Coruna, Spain.

Y. Gan. J.N. Weng(2010). Fast Constructing Large Scale City 3D Building Scene Based on 2D Building Outline. The 18th International Conference on Geoinformatics 2010,June 18-20, Beijing, China.

Z.Y. Xu, T.H. Ai, Y.J. Wei, G.R. Zhu(2006), "Research On Visual Variables of 3D Map Symbol". Geomatics and Information Science of Wuhan University. Wuhan , vol. 31, pp. 557-560, Junu 2006.

M. Kada(2005). 3D Building Generalisation. The International Cartographic Conference,2005,July 9-16, Coruna, Spain.

A. Çöltekin(2005). A VISUALIZATION METHOD BASED ON FOVEATION. The International Cartographic Conference,2005,July 9-16, Coruna, Spain.