

AN VISUALIZATION MODEL OF GLOBAL IMAGES BASED ON QTM

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ABSTRACT:

Constructing interactive visualization model of global image data is one of the hot research topics in Geo-spatial information sciences. Conventionally, global image data is used as texture in visualization models. Those methods aim to get excellent visualization effect and more attention is paid on improving the speed of image visualization. However, interactive operations, which are the bridge between user and visualization systems, are neglected and this leads to difficulty of spatial analysis in visualization circumstance. To overcome those deficiencies, a new interactive visualization model of global image data based on QTM (Quaternary Triangular Mesh) is presented in this paper. Our approaches start with QTM partition on the spherical surface and visibility culling for improving the speed of image data visualization is described. Then, interactive operations and the implement details of this model are presented. In the end, the experiment is made to test the algorithms and methods approached in this paper by using of Wsearth.tif data with 256 gray levels in ArcGIS. The results illustrate that: 1) the methods and algorithms approached in this paper are correct and effective; 2) the QTM number and calculating amount for finding QTM in visible frustum are nearly invariable in visualization with the technology of visibility culling.

1. INTRODUCTION

Constructing interactive visualization model of global image data is an important part of "Digital Earth", as well as one of the hot research topics in Geo-spatial information sciences. Traditionally, image is used as texture and mapped onto the surface of sphere in visualization models. Those models have been used in visualization software widely, such as Google Earth, ArcGlobe, Skyline etc [Skyline white paper 2005; Grosser 2006; Crawford et al 2003; Bjørke et al 2003, 2004]. However, interactive operations are neglected in these systems and this leads to difficulty of spatial analysis in visualization analysis.

To overcome this deficiency, various interactive visualization models have been proposed [Xie et al 2007, Nguyen and Worring 2007, Brooks and Whalley 2007]. Those models are effective to support local or small area image visualization. However, they are constructed in planar Euclidean space and unfit for global scale image because a spherical surface belongs to manifold space and is not topologically equivalent to planar Euclidean space in geometry. Therefore, a new interactive model based on sphere surface with the structure of QTM (Quaternary Triangle Mesh) is proposed in this paper.

QTM is one of common global discrete grids, which consist of a set regions that form a partition of the Earth's surface and can be hierarchical subdivided optionally. QTM can be used to simulate the earth surface when they are recursive partitioned to a certain degree and can be used to resolve those problems caused by projections [Dutton 1999]. They can be considered as the basic cells of global image data. And in this way global problems and phenomenon, such as global spatial data index [Goodchild and Yang 1992; Alborzi and Samet 2000], digital map generalization [Dutton 1996; 1999], environment monitoring [White et al. 2000] global climate modeling [Thuburn 1997] and global grid position system [Clarke et al 2002; Sahr et al 2003] etc, are analyzed based on those cells. Although the correlative theory and applications on QTM are studied widely

by many scholars, to the best of our knowledge, there is no prior work that attempts to solve QTM data visualization interactively. Existing visualization models based on square grids are not fit for visualizing QTM data because of different geometry characteristic of QTM and square grids. Sphere TIN visualization methods are also not suit for QTM's. The reason is that QTM has good hierarchy, which is very useful for multi-resolution spatial data visualization, while sphere TIN is irregular and its hierarchy is very poor. Therefore, it is necessitous to construct a new interactive visualization model based on QTM. In this model, QTM is considered as the basic cell for representing global image data and spatial analysis can be implemented based on those cells.

Following this introduction is a section presenting the principle of QTM partition in brief. This is followed by the presentation of interactive visualization model based on QTM. In section 3.2, to improve the speed of visualization, visibility culling is presented in detail. Then, iterative algorithm for visibility culling is presented. Following that, wsearth.tif (which is from ArcGIS) is used to test methods and algorithms approached above. Finally, the conclusion and recommendation for future work will be presented.

2. PRINCIPLE OF QTM PARTITION

The QTM structure used in Fekete [1990], Dutton [1989; 1999], and Goodchild and Yang [1992], are all based on inscribed octahedron. The reason is that its vertices occupy cardinal points and its edges assume cardinal directions, following the equator, the prime meridian, and the 90th, 180th and 270th meridians, making it simple to determine which facet a point on the planet occupied [Dutton 1989]. When a triangle is subdivided, the latitudes/longitude pairs of any two of its three vertices are averaged to yield edge midpoint location. Clearly after each level of subdivision, the triangle become smaller, and at the 21th level of subdivision, their sizes are approximately

1m, going down to 1 cm at 28th level. Fig.1 illustrates subdivisions at level 1, 2, and 3.

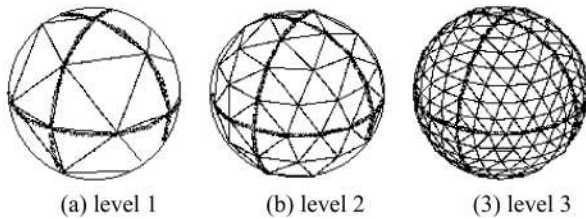


Fig.1 QTM partition of spherical facet based on octahedron [Dutton 1989]

In term of the regularity of the subdivision, the QTM structure has several attractive properties, for example, the topology of the QTM makes neighbour search easy, and the tessellation is regular, hierarchical, and numerically stable everywhere on the spherical surface. Thus, QTM is used for global spatial data management widely and good hierarchy of QTM is benefit for multi-resolution data visualization quickly.

3. VISUALIZATION MODEL BASED ON QTM

3.1 The Principle of QTM Data Visualization

The main task of visualization is that each cell data is rendered in display device space according to some projection principles. In other words, spatial coordinate of image should be transformed into screen coordinates in visualization. The detailed steps of projecting one QTM into screen space can be described as following: first, geographical coordinates of QTM vertices are figured out according to its codes (See Goodchild 1992); then spatial coordinates of them can be computed based on formula 1; next, QTM vertices are projected into view frustum and the function to transform projection coordinates into screen coordinates is provided by development language, such as OpenGL. After that, a plane triangle on screen is formed by connecting those projected QTM vertices. Thus, the whole process of rendering a cell is finished.

$$\begin{cases} X = R \times \text{Cos}(\text{Lat}) \times \text{Cos}(\text{Lon}) \\ Y = R \times \text{Cos}(\text{Lat}) \times \text{Sin}(\text{Lon}) \\ Z = R \times \text{Sin}(\text{Lat}) \end{cases} \quad (1)$$

In which, R is the approximate radius of earth; Lat/Lon is the geographical coordinates of QTM vertex, Lat is the latitude, Lon is the longitude; (X,Y, Z) is spatial coordinates of QTM vertex.

3.2 Visibility Culling

To improve the speed of QTM visualization, visibility culling should be applied. Visibility culling is an effective technique for reducing unnecessary rendering computation by eliminating invisible portions of data before visualization. Visibility culling has been an important composition part of visualization and has been widely used in many visualization systems.

To implement visibility culling, computing view range(frustum) and judging the relation of image and view frustum should be implemented. Conventionally, view range is related with projection references, such as the position of view point, view distance etc. Traditionally, perspective projection is selected in visualization and view frustum is used for representing visualization range. The relation of view point and view frustum is shown as figure 2.

Following this, to judge image data whether locating in view frustum or not becomes another important task in visibility culling. View frustum belongs to 3D space. It is clear that ascertaining the topology relation of two objects is difficult in 3D visualization circumstance relatively. To simplify the process of visibility culling, a new method is approached in this section. In this method, a rectangle, which is the range of projecting view frustum into far plane and is called as view-rectangle, is gotten firstly. Next, minimax enclosing triangle or rectangle of image, which is used for representing the range of image data, is also projected into far plane in view frustum. If all or parts of images locate in view-rectangle, those images should be rendered during the process of visualization. On the other side, the result is contrary. In this way, a problem to judge the relation of two spatial ranges in 3D circumstance is transformed into 2D space problem. This is very useful for reducing heavy computation in visibility culling. It is clear that view frustum is changed with the changing of the position of view point and view angle. And visibility culling should be carried out repeatedly during image visualization.

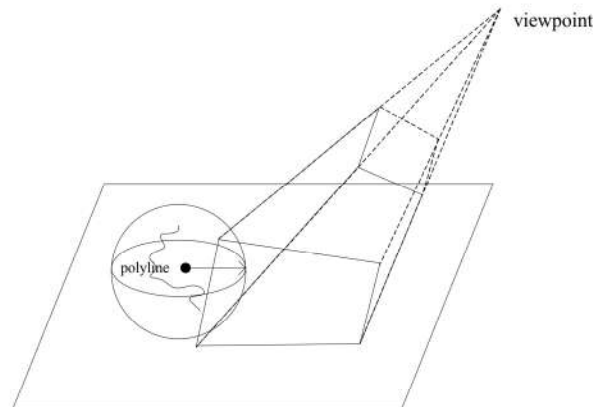


Figure2. The relation of view point and view frustum

3.3 Constructing Pyramid Model Based on QTM

Pyramid model is another effective way to improve the speed of image visualization. Pyramid model provides that more image details are rendered when the object is very close to the viewer, and are replaced with coarser resolution images as the object recedes. QTM has good hierarchy and this is very useful for constructing pyramid model based on QTM. The detail of constructing pyramid model can be described as following. First, four equal-resolution QTMs, which have the same father-QTM, are selected and incorporated into one lower-level QTM. Then, the value of this new QTM is figured out according to some rules, such as getting the average value of four origin QTMs etc. The steps approached above are repeated and pyramid model based on QTM is constructed.

After that, selecting the right level QTM for visualization has been next important question. The main principle to decide loaded QTM level is that average size of loaded QTM is

approximately equal to the range that one pixel represents. The range of one pixel can be figured out by computing the spatial distance of two adjacent pixels. The detailed steps can see the Goodchild[1992] literature.

3.4 Implement of Interactive Operation

Interactive operation has been a useful tool for operating image, and is the communication bridge between user and visualization system. It is one of important composing parts of visualization and is the base of spatial analysis interactively in 3D circumstance. Some simple interactive operationis implemented based on this, such as finding the spatial position of pixel, calculating area and length of QTM etc.

In visualization system, only screen coordinates can be gotten directly. So, transforming screen coordinates into spatial coordinates can be the base of interactive operation. And this can be carried out with the help of some system function in development circumstance, such as UnProjection function in OpenGL etc. After acquiring the spatial coordinates, some interactive operations, such as calculating the distance of two QTM, figuring out area of QTM etc, can be implemented.

4. ITERATIVE ALGORITHM FOR VISIBILITY CULLING

In this section, detail of visibility culling based on the relation of view range and QTM vertexes is presented. QTM has good hierarchy. It is clear that if one QTM does not locate in view frustum, its son QTMs dose not also locate in view frustum. Based on this principle, the iterative algorithm for visibility culling can be implemented. The detailed steps can be described as following. Suppose that there is a N-level QTM. The detail steps to decide that whether this QTM and its son-QTM locate in view frustum or not can be described as following.

First, view range should be figured out according to projection reference, such as view distance, view angle etc;

Then, the QTM level in visualization, which is called as display-level, is ascertained. The size of corresponding display-level QTM is nearly equal to the spatial size of each screen pixel.

Next, spatial coordinates of QTM vertexes are computed. Loaded QTM can be ascertained based on the relation of QTM vertexes and view range. The details of this are described as following.

- If N is equal to display-level and three vertexes of QTM are out of view frustum, this QTM is not rendered in visualization(shown as figure3.c). In the others cases, this one is painted in view frustum(shown figure3. a,b).
- If N is less than display-level, there are three cases should be deposited. First, if three vertexes of one QTM locate in view range, its son-QTM should be rendered; second, if three vertexes of one QTM are not in view range and four edges of view range are also not in QTM, this QTM should not be represented; in the others cases(shown figure3 d,e,f), QTM should be subdivided and its son-QTMs would be judged.

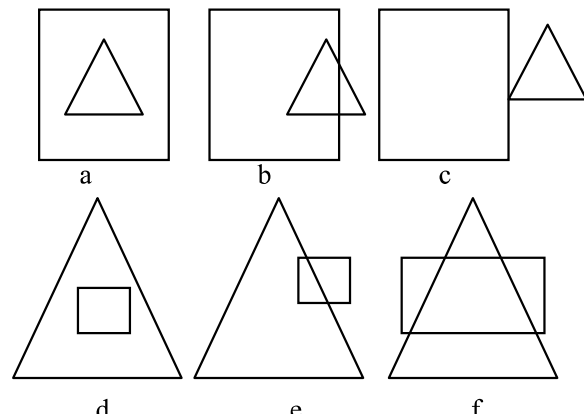


Figure 3 The relation of QTM and view frustum

According to the method discussed above, eight first-subdivided QTMs are to be tested. In this way, QTM, which locates in view frustum, can be found and visibility culling is implemented correctly.

5. EXPERIMENT

Experiments of visualization and visibility culling have been done by using of Wsiearth.tif data with 256 grey levels in ArcGIS. The computations are performed on a processor 2.2 GHz Pentium IV PC, with 512MB of RAM and 64M GeoForceIV graphics.

The Wsiearth.tif image is transformed into 12 levels QTM pixels. Visibility culling is implemented based on the method approached above and the result is shown as table 1. From this table, with the changing of view distance and angle, different level QTMs are loaded in visualization. Required computation times for implementing visibility culling are between 2912 and 16906 milliseconds. The number of QTM rendered in view frustum is about 7378836-240152. It is obvious that the QTM number and calculating amount for finding QTM in visible frustum are nearly invariable in visualization with the technology of visibility culling. The effect of different level QTMs are shown as figure 4. Interactive operations of QTM are shown as figure

6. CONCLUSION AND FUTURE RESEARCH

Constructing global interactive visualization model remains a challenging vision. Interactive visualization of global image is one of the fundamental problems in Geography and Spatial information Science. In this paper, a global interactive visualization model of image is approached based on QTM.

In this model, QTM is considered as the basic visualization cells and interactive operations and spatial analysis can be implemented based on those cells. One contribution in this paper is developing an iterative algorithm for visibility culling. The experiment illustrates that the algorithm not only is efficient, but the QTM number and calculating amount for finding QTM in visible frustum are nearly invariable. Another contribution of this chapter is the presentation of constructing pyramid model base on QTM. In this way, multi-resolution image visualization can be implemented smoothly. Our analysis indicates this model provides an efficient, smooth and acceptable representation of the global images.

view distance	view angle(°)	Level of selected QTM	computation times(millisecond)	the number of QTM in view frustum
1.1R	40	10	13408	737836
	30	10	10720	385484
	20	11	14592	655292
	10	12	14432	645592
	5	13	14320	645576
	2	14	14816	427660
1.01R	40	10	15936	627072
	30	10	2736	238288
	20	11	16160	561728
	10	12	15952	555588
	5	13	15808	559124
	2	14	2832	241008
1.001R	40	10	16906	615928
	30	10	2896	237496
	20	11	16128	552028
	10	12	16080	546288
	5	13	15872	549976
	2	14	2896	240180

Table1. Visibility Culling according to View Distance and Angle

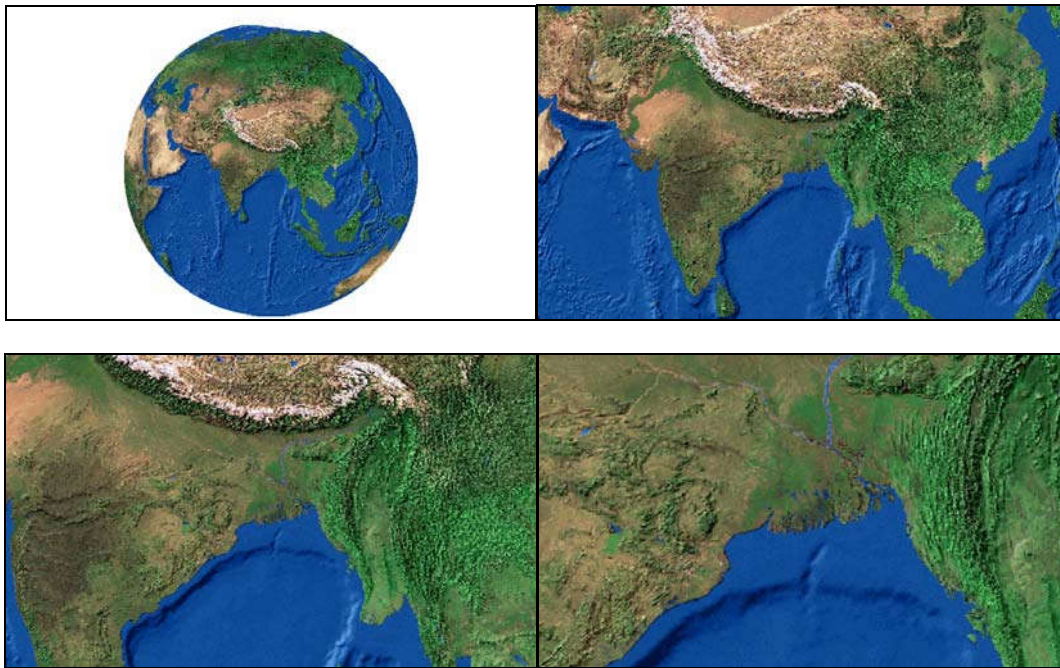


Figure 4 Visualization of different level of QTM

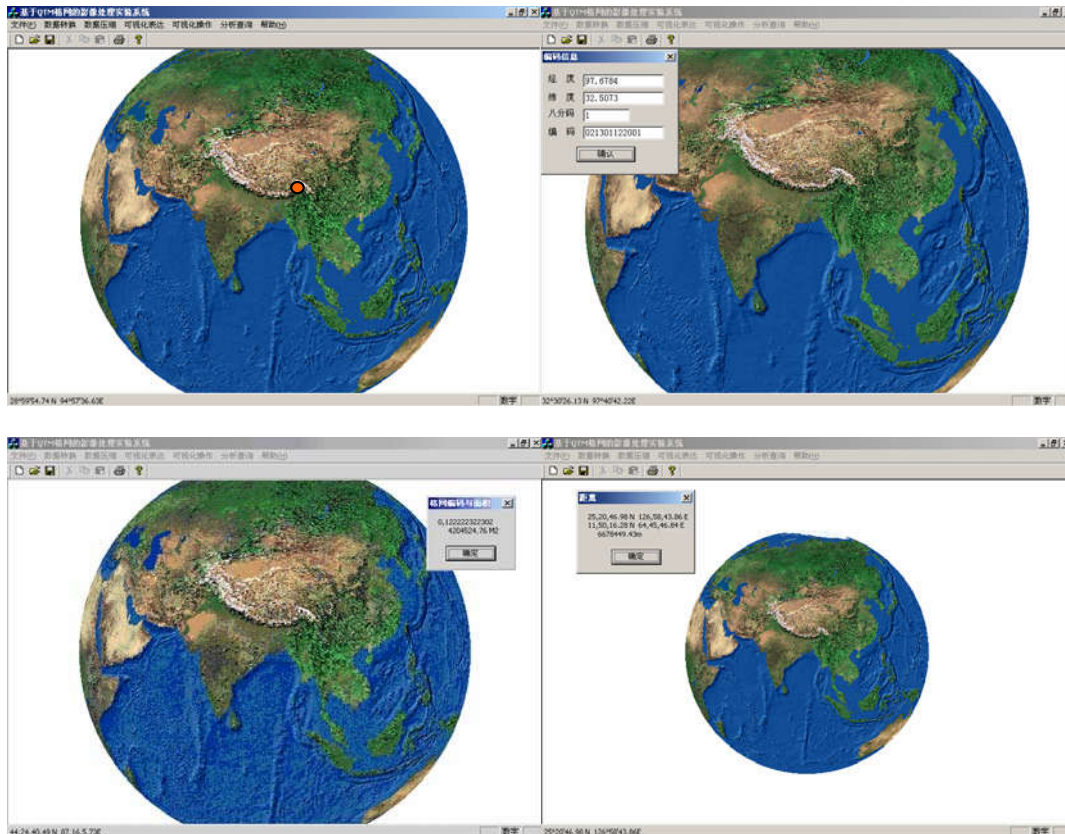


Figure 5 Interactive operations in visualiza

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