STUDY ON 3D TERRAIN VISUALIZATION ON INTERNET

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ABSTRACT:

With the analysis of the already existed theories of 3D terrain visualization, it is argued that how to use Digital Elevation Model to construct 3D terrain models on Internet, in the light of Level of Detail technology in this paper. Finally an application system is developed to real-time display and operates the terrain on Internet.

1. INTRODUCTION

Terrain visualization is a technology that studies the display, simplification and simulation of Digital Terrain Model or Digital Elevation Model , so DEMs is one of the most important components that consist of 3D terrain visualization. It is the carrier of all kind of information and also the basic framework of 3D virtual earth.3D terrain visualization models are constructed on the base on DEM data in this paper. At current time, with the rapid development of computer software and hardware technology, network technology, multi-media technology and virtual reality technology and with the appearance of the theories of mathematic morphology, fractal subject and wavelet transformation, 3D visualization has made greater progress. The advancest and most colorful fashions are the area of simulation and 3D visualization, such as flying and radar simulation. In general, the precondition of accomplishing 3D terrain visualization is the uniform coordinates, such as WGS-84;In order to construct a continuous and seamless DEM database for the country or even the earth, and geographic coordinates are adopted. It also contains the following technologies:

(1) Internet technology: In order to accomplish 3D visualization on Internet, enough network bandwidth and data transmission must be ensured. However, the current Internet data transmission capabilities and rate are limited and the terrain data are massive, so some methods must be used to enhance the real-time browsing speed of 3D terrain on the browser on Internet.

(2) Virtual Reality technology: Enhancing 3D environment is one of the important content of 3D terrain visualization. Besides using lighting technology to make the terrain have light and shade, image textures (satellite images, color terrain maps) and raster information (roads, rivers and buildings) need to be covered on the DEM data. Because of the condition limitation, high-resolution images are difficult to be gotten under some environments, and color render is the important way to abstain the reality of terrain. We also develop the seamless connection of the terrain and roam or zoom the terrain from the local to the whole earth, constructing virtual reality, which users can walk freely, operate with other virtual objects in virtual environments created by computers.

In this paper, the authors constrate on three main contents, according to the hotpots of the 3D terrain visualization:

(1) The relative 3D terrain visualization technologies are illustrated in the paper.

(2) Constructing 3D visualization models using DEM data; Putting forward B/S architecture in which the system can accomplish such functions as real-time dynamic display, seamlessly browse, and actively operate the terrain and zoom in or zoom out the terrain with the eye points far closer or away.

(3) Illustrating the key technologies of 3D terrain visualization, including coordinate transmission, 3D visual models, Color rendering, fast display on Internet.

2. TERRAIN VISUALIZATION TECHNOLOGIES ON INTERNET

2.1 OpenGL Graphic Library

OpenGL (Open Graphic Library) is a 3D graphic standard based on GL (Graphic Library) created by AT&T corporation, UNIX software lab, IBM corporation, DEC corporation, SUN cooperate, Microsoft cooperate and SGI corporation. OpenGL is actually an interface of graphics and hardware. It is independent of hardware device, window system and operation system. As an open graphic standard, the software programmed by OpenGL can be transplanted between UNIX system and Window 2000/NT;In addition, OpenGL is transparent for network and can be allowed to draw in local and remote computers in Client/Server architectures.

2.2 ActiveX Control

ActiveX control is a new technology based on OLE technology. It base is COM (Component Object Model) technology and it is a public framework in order to extend the functions of Microsoft Web browser IE.ActiveX Control is similar to Plug in Control, but ActiveX control is used by any language or application system that can provide OLE standard. Plug-in can be used in some specific browsers.

ActiveX control can be provided only by IE.if Users use ActiveX control and the client has no the control, the system can ask to download it. After the control has been downloaded, it will be registered automatically. ActiveX control executes fast and can be accomplished by many languages. So we can copy the source codes and improve software development efficiency (Yang and Wang, 2001).

2.3 Level of Detail Technology

In the real-time display of 3D terrain, the graphic data needed are more than those that are real-time displayed by hardware, and the application model's complexity often extends the present graphic workstations really deal with data. Considering the graphic complexity is almost indefinite, 3D terrain data simplification is one of the important research contents of terrain visualization. There are two categories: one is refreshment; the other is decimation (Cignoni, et al., 1997). The simplest method of terrain simplification is that only displaying the part data relative to the window, but it is not enough, because the view of point is far away the view port may extend a broad area. The current technology adopted is LOD (Level of Detail). LOD technology is a series of models that are gotten through different level of decrypting methods for a large scene or in its objects. These models are chose to render the terrain. Namely the terrain has more detail with the view point is closer, and the terrain has less details with the view point is far away from the terrain.LOD models generally have three formats:

(1) Discrete LOD Model: Different aspects of the same model have the same level of detail; neighbor LOD has "bounce", when switching each other. Because different LOD models are irrelative on topology structure, so the discrete LOD technology has an obvious fault, namely there is obvious "bounce" on vision, when the terrain is displayed and switches each other.

(2) Continuous LOD: Different aspects of the same model have the same level; neighbor LOD can accomplish smoothly transition. The advantage of the methods is that neighbor LOD models have little difference, and has a little "bounce " on vision, when the neighbor LOD switches.

(3) Multi-Resolution Model: Different levels of detail exist in the different areas of the model at the same time, which has been put forward a method by some experts that simplifies data. It can adopt the models having the same or different resolutions in the whole area, according to the need, and simultaneously ensure the terrain continuity.

3. SYSTEM ARCHITECTURE

Browser/Server architecture is adopted to construct 3D terrain visualization on Internet. Terrain data and image texture data are put in the server; the browser is responsible for downloading terrain data and texture data to create 3D terrain. Figure 1 is the architecture of the system.

The server mainly contains application programs,DEM database, image database, Web server.Imge texture,3D model's texture(trees,bulidings) are put in the image database;DEM data are put in the DEM database.DEM data are needed in this paper have three parts:

The first part is the JGP95E 5´ Global Topographic Database edited by The defense Mapping Agency and NASA/Goddard Space Flight Center in USA.The database has 2161 records, its resolution is 5´×5´.The second part is GTOPO30 edited by Geological Survey's EROS Data Center(EDC),its resolution is 30″×30″,and the basic grid distance is about 1km. The third part is Changjiang River's DEM data, its resolution is 0.3″×0.3″,and its basic grid distance is 12.5km.

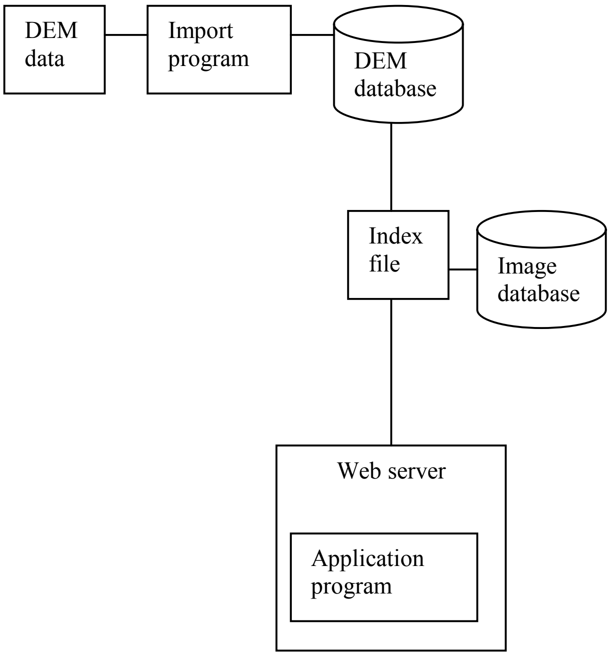

Figure 1. Architecture of the Application Demo System

Some optimal methods must be adopted to organize and index the data, in order to abstain real-time active operation of the scene on Internet for so massive data.

The system divides the terrain data and texture data into different resolution DEM data in the light of pyramid data structures through the imported programs, and then summits to SQL server; The system has specially constructed huge and multi-scale image database for the massive data of the large areas, then creates uniform spatial index according to their geographic distributing, so the image database can connect with the DEM database to create real 3D terrain scene. The format of the index file is: the numbers of LOD and some information of every LOD, including the numbers of DEM or images' file, filename and the coordinates' extends of DEMs.

3D terrain redendering, roaming and spatial analysis are integrated in ActiveX control. The users only download the control on the client and then it will be registered by the system. The users will use the functions of the application system. Figure 2 is the architecture of the browser.

4. THE KEY TECHNOLOGIES OF 3D TERRAIN VISUALIZATION

4.1 Coordinate Transmission

Visual maps created by 3D terrain data through geometry transmission, projection transmission, clipping transmission and view port transmssion. OpenGL makes the vertexes and other information translated into 3D maps according to the principles. Object coordinates are the world coordinate but not the general Cartesian coordinates. Model-view matrix applies these coordinates to create observing coordinates, projection matrix applies the observing coordinate to create clipping coordinates, which create device coordinates, and finally view port transmission translates the device coordinate into window coordinate in which the scene is drawn.

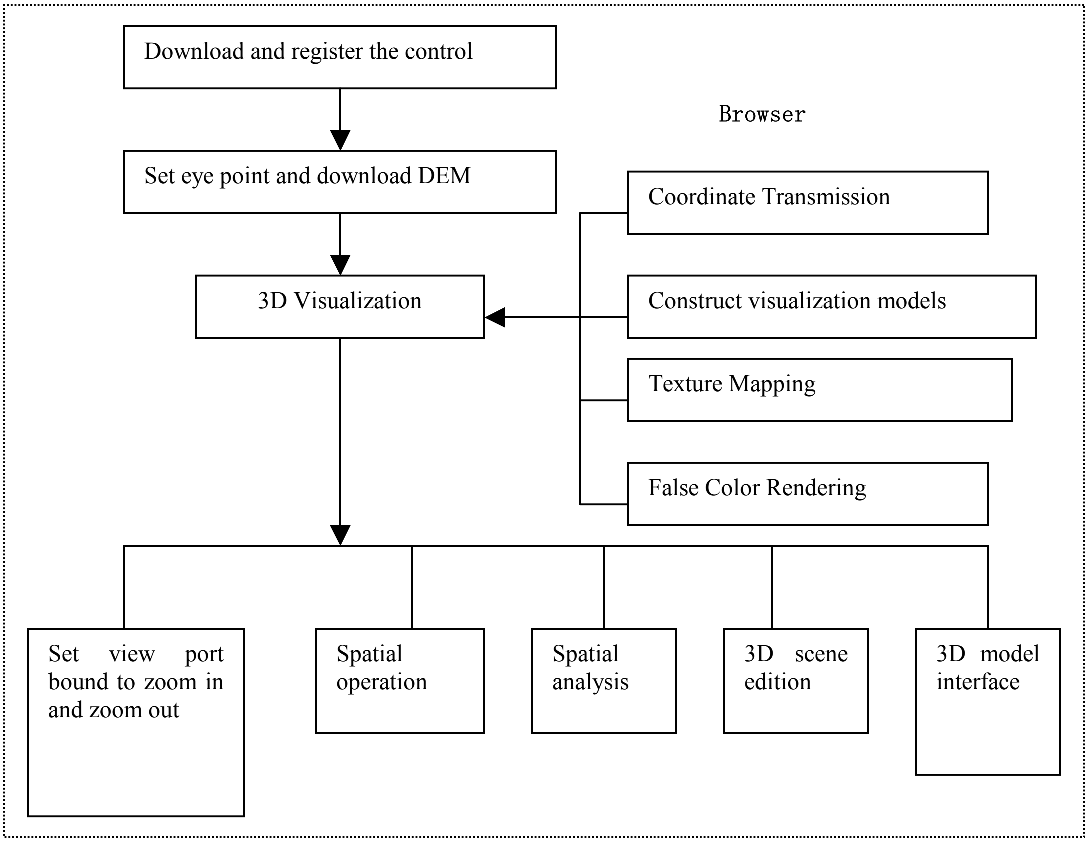

Figure 2. The Client's Flow Chart

$$\begin{cases} x = (N + H)\cos B \cos L \\ y = (N + H)\cos B \sin L \\ z = [N(1 - e^2) + H]\sin B \end{cases} \quad (1)$$

$$N = \frac{a}{\sqrt{1 - e^2 \sin^2 B}} \quad (2)$$

N is curvature radius of the point P on the earth, a is the ellipsoid and a=6378137m, e^2 = 0.00669438499959.

In order to accomplish the terrain visualization, the Geocoordinates are translated into spatial right-angle coordinates. WGS-84 Ellipsoid is adopted to accomplish 3D terrain visualization in this paper. The center of WGS-84 Ellipsoid is consistent with WGS-84 spatial right-hand coordinate, so corresponding to any point P on WGS-84 Ellipsoid, Its transmission relation of Geocoordinate (B,L,H) and its spatial right-hand coordinate(x,y,z) is that:

$$\begin{cases} x = (R + H)\cos B \cos L \\ y = (R + H)\cos B \sin L \\ z = (R + H)\sin B \end{cases} \quad (3)$$

In the above equation(3),R is the earth's radius,L,B is Geocoordinate, $-90^0 \leqslant B \leqslant 90^0$ and $-180^0 \leqslant L \leqslant 180^0$.

4.2 Layered Rendering the Scene

In order to make the terrain more real and Stereoscopic, the terrain need to be rendered using different color in the light of the height of the terrain. For example, using blue color to render the rivers or sea and using umber color to render the plateau. The following steps illustrate the method of determining every pixel (Fig 3):

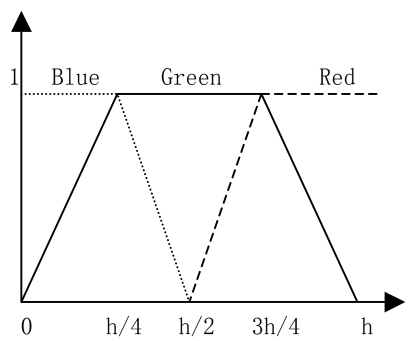

Figure 3. Illustration of Layered Render

(1) Assuming that there are N kind of colors which can be used, then a area that the maximum height is ΔH can be divided into N height bands. Every height band is given one color. Using $color_i$ denotes every layer's color, so the relationship between the *Height* and $color_i$ is:

(2) When rendering every polygon slice, every pixel's color can be gotten in the light of the interrupted height using scan increment method (Wang, 2000).

4.3 Setting Eye Point's Bound and Constructing 3D Terrain Models

Terrain data are the regular grid data and are a dimensional matrix containing height information, the point's coordinate of the terrain can be calculated through the original point's longitude and latitude and grid's space between, so the methods of terrains constructed by using regular grid are simple. The terrain data through coordinate transmission may be used to construct rectangle grid and create 3D visualization models.

According to the principle of computer Image and graphics, we must know the location of eye point (*eyex,eyey,eyez*), the position of the reference point(*centerx,centery,centerz*) and the direction of the up vector(*upx,upy,upz*).In order to accelerate the display speed of 3D terrain, we should draw the scene inside the display bounds. View bounds are set around the reference point and view bounds are relative to the distance between eye point and the center of the scene, namely when the eye point is closer to the center of the scene, the view bounds are smaller, or else the bounds are bigger. The scale between the eye point and the center of the scene is as follow:

$$\{eyex, eyey, eyez\} = fScale\{centerx, centery, centerz\} \quad (4)$$

$$LOD_i = N, if\, 1.00f < fScale < d_i \quad (5)$$

In the above equation, $fScale$ is the scale factor, *N* is the numbers of LOD, *N*=1,…n, *d* is a positive number that is bigger than 1.00.

With the decreasing of scale factor *fScale*, namely the closer between viewpoint and the center of scene, the higher level of DEM will be transferred to draw the scene. Then equation (6) decides the level of DEMs,and DEM data that satisfy the displayed conditions will be calculated, according to the index file and the rectangle that its center is the reference point; finally the ActiveX control downloads the data from the server. After using equation (3) and regular GRID model to construct 3D visualization model, the control transfers the display list to finish 3D terrain's dynamic display. With the process of the center of the scene, the scene also moves, thereby we abstain the goal that the earth can be real-time seamless roamed

4.4 Fast Display Mechanism

Real-time dynamic display is one of the basic requirements of 3D terrain visualization on Internet. Display list can accomplish fast display of 3D terrain. Display list is a series of OpenGL cache and it needn't organize the memory. Display list stays in the server, so network transmission greatly decreases and increases the performance of the network. In addition, geometry models containing massive data are put in display lists and are processed into the format that fits the hardwares.that advantage is that the executed time is very short, when the display lists are transferred. After ActiveX control downloads DEM data from the server and creates display list, the control will delete the data from the memory in order to decrease the space of the memory. So the application system needn't download and read the data and construct the models every time, but accomplishes 3D real-time active operation through the display lists. All above mechanisms introduced are adopted to accelerate the display speed on Internet in this paper.

Figure 4. 3D Visualization of Global Terrain

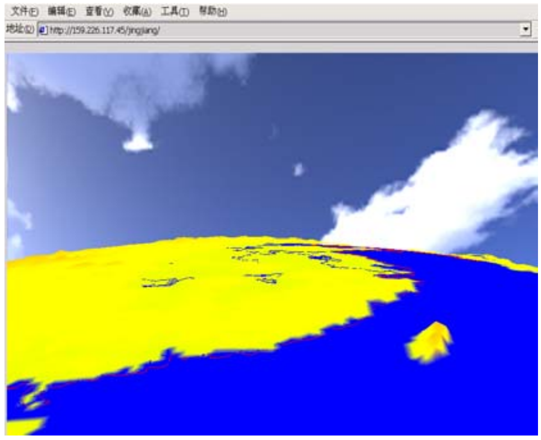

Figure 5. 3D Visualization of A Part of The Earth

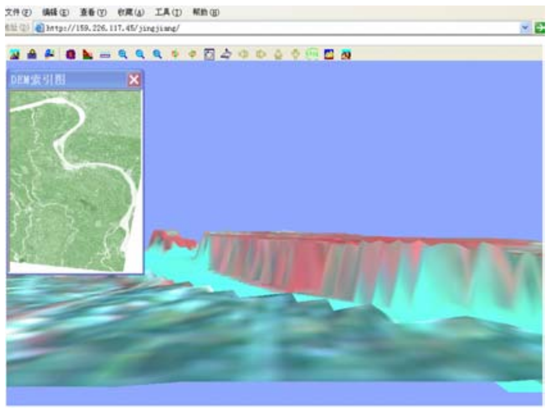

Figure 6. 3D Visualization of Yangtse River

5. RESULT AND PROSPECT

3D terrain visualization on Internet is accomplished in this paper. Different users can browse and operate the scene in different palce, which help information share.3D terrain visualization is based on WGS-84 ellipsoid, So it decreases the errors of coordinate transmission terrain projection transformation. The system in this paper also accomplish such function as image coverage, false color rendering, roaming along the given routine, 3D spatial analysis and so on. The system also has accomplished the terrain's infinite zooming out or zooming in. We can not only view the whole areas, but also view the detail of the local areas. In the same view frustum, the system can transfers different level of data, according to the distance between then eye point and the destination point; users can view the scene from different angles or different viewpoint.

At present, the author is studying on covering different kinds of information on the terrain, such as roads, rivers and plants, integrating the organization of spatial vector data and attribute data, and 3D spatial analysis with the system. Providing a technical way for direct and correct decision.

Because the complexity of 3D terrain visualization on Internet and the intersection of muti-subjects. There are many theories and technologies need to be solved. The author will continue to attend the development of the area, and improve the existing system.

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