3D HIGHWAY LANDSCAPE MODELING AND VISUALIZATION

Qingquan LI, Xiaoqing ZUO, BiSheng YANG

Research and Development Center of Spatial Information & network Communication, Wuhan University,
129# Luoyu Road, Wuhan 430079, P.R. China, email:lqq@wtusm.edu.cn, zuoxq@263.net

Commission V, WG V/6

KEY WORDS: Highway, CDT, strip-distributed, multi-thread, Buffer-Quadtree

ABSTRACT:
In this paper, data model and structure of the 3D road model, which is constructed by Constrained Delaunay Triangles (CDT) and integrated with terrain model, are proposed first, and the method of judging the maximum angle was used to build the triangle net. Considering the characters of strip-distributed and data volume of highway, the following two methods are developed to enhance the 3D roaming velocity. One is the multi-thread technology; the other is the brief “Buffer-Quadtree” technology, which is developed based on Quadtree, by creating a buffer along with the data block edge, And then code for every data block using a rule of linear Quadtree. According to the view coordinate, using multi-thread, we can decide that which block will be loaded. Finally, a software prototype “VirtualWay”, which is developed by Vc++6.0 and OpenGL, is introduced, and several experiments are done to proved the methods feasibility.

1. INTRODUCTION

As the rapid development in construction of transportation in China, more and more highways already have been running or will be going to run, therefore, managing old highways, surveying and planning new highways is a very hard work to transportation department. So they cried for an intuitional and modern running means base on virtual reality system, this system should include model generation, dynamic visualization of highway’s 3D landscape, roaming at one’s will, editable and operational. And with these help, the work of making-design become more science, their work’s level and efficiency is improved, and the cost of running works is reduced.

In recent years, there is a lot of literature concerning 3D landscape, especially for the terrain surface simplification methods, such as Level of detail (LOD) or multi-resolution. So far, some researcher have put forward some efficiency algorithms in this field, such as Multi-Resolution 3D Approximation Optimization (Hoppe, 93), Hierarchical Dynamic Simplification (Luebke, 97), Dynamic View-Dependent Simplification (Xia, 96), View-Dependent Refinement of Progressive Meshes (Hoppe, 97) and Progressive Simplicial Complexes (Popovic, 97)[5] etc. These algorithms can solve some problem well, but at the same time, it may either brings on data redundancy, or make the data structure more complexity to design program, especially concerning strip distributed terrain data. So, take into account this, a improved algorithm based on Quadtree will be introduced. In this paper, the main objective is described as follow:

1). Discuss data model and structure of the 3D road model, which is constructed by Constrained Delaunay Triangles(CDT) and integrated with terrain model.

2). Considering the character that strip distributed terrain data, and the mileage of highway is long, multi-thread and the brief “Buffer-Quadtree” technology be used to improve the roaming efficiency.

2. DATA MODEL AND DATA STRUCTURE

The highway is building upon terrain, so the terrain model should be considered first. Digital Elevation Model (DEM) is the general method of represent terrain, and TIN is the best selection to represent DEM[6]. The theory of creating TIN in a general had been studied and applied in deeply, and some researchers have a enough efficient investigated to tackle with the strong strip distributed terrain data(such as railway, highway etc). In literature[7], the author pay enough attention to the fact that single data cluster can affect a very local region, put forward a analogous constraint delaunay triangles generation algorithm.

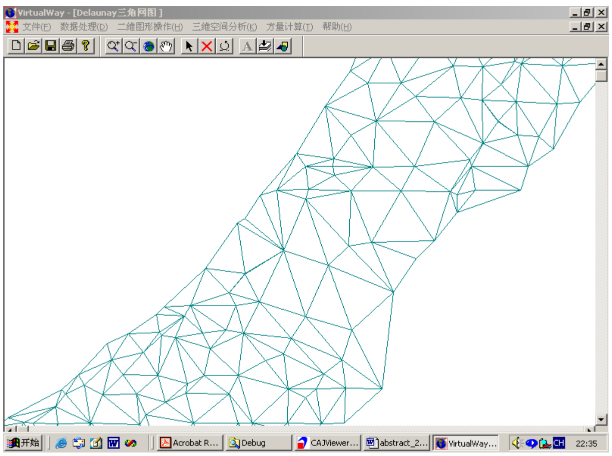

Figure 1. TIN of strip distributed data

And the algorithm in literature[7], the region boundary data which ordered by anticlockwise should be provided, but in fact, we have much difficult to obtain these boundary data. Consider this, we eliminate the distortion triangles on these boundary nodes by judging the maximum angle, then build the model of strip distributed terrain data, the maximum angle can be adjusted according to the shape of terrain, the TIN model in Figure 1 is a case of applying this algorithm.

Then, to the road model, because its boundary node data can be acquired easily from road design document, the algorithm of literature [2] was used, such as Figure 2.

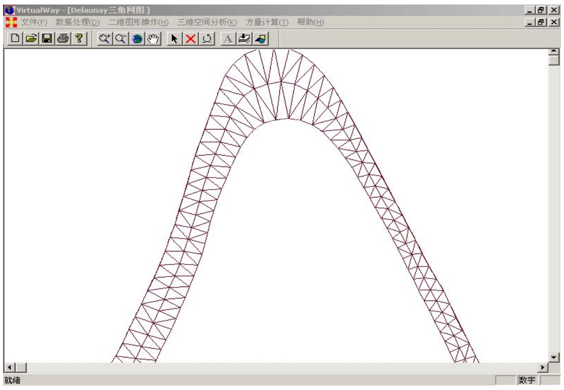

Figure 2. TIN of road

In general, it has lots of roads in a scene, that is to say, there are many road TIN faces to be managed or organized, including their topo-relation. In this paper, every road TIN face would be regarded as one object. And the structure of the object is listed as follow:

```
class RoadTIN :public Object{
long   m_ID         //road ID code
long    m_npCenterNumber; //the number of node in the center
            line
POINT3D  *m_pRoadCenterPList;
            //the list of the midpoint
long    m_npNumber;  //boundary node
POINT3D  *m_pPointList;  //boundary
                               //node list
float   m_Width;      //road width
long   m_TriNumber;  //triangle number
Tri_Struct  *m_pTriList;    // triangle list
…}
```

Base on above structure, we can calculate the road length, render the highway 3D landscape, and get transect or vertical section, embed in terrain model etc. Some times, as the road is too long,

Road ID	Begin road ID	End road ID	Main or branch (1 is, 0 no)
1	-1	2	1
18	17	19	1
26	1	-1	0
…	…	…	…

Table 1. Road topo-relation

we can't help but divide it into several segments, in addition, the branch roads also to be considered, so we designed a brief structure to save them as table 1.

As we know, there are many subordination along the road, like building, bridge, and counterfort etc. So, those roads and subordination should be integrated into terrain model, and when the terrain-object, such as building, counterfort, is tessellated into the terrain model, it will rebuild the correlative local triangles and their topo-relation, and update terrain's TIN at once. So the terrain model, road and building model etc, will be integrated.

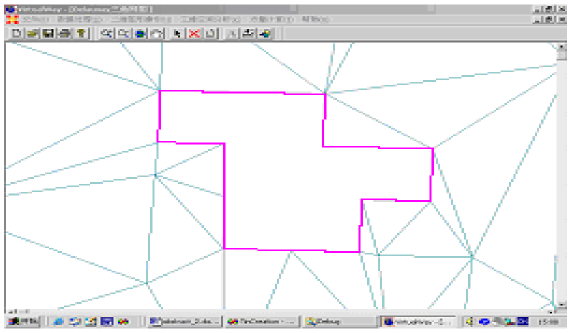

Figure 3. Update the TIN after insert a polygon

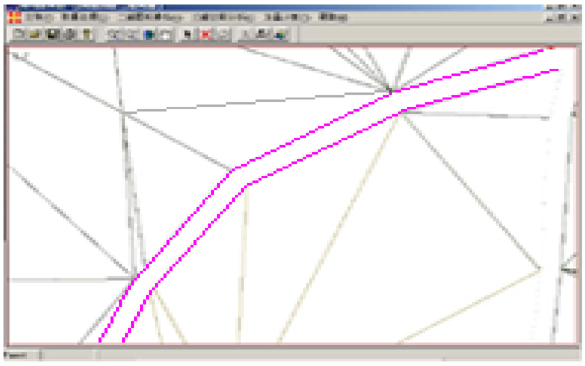

Figure 4. Update the TIN after a road tessellated

3. VISUALIZATION

The highway manager and designer have earnestly long for the virtual landscape of the project produced by integrating geographic spatial data with integration model of design.

In order to build a 3D scene, the follow work should be done in turn, transformation of the reference frame, projection transformation, light source set, putting the material and texture coordinate to the vertex of digital terrain model and highway design model or other models, thus, the highway virtual landscape real-time roaming system is formed, and dynamic scene can be viewed.

After the 3D scene building, the roaming velocity should be considered. In order to improve the volume terrain data roaming velocity, in this paper, two methods will be used. 1) The multithread technology is applied in the program; 2) we called "Quadtree-buffer" algorithm, which the terrain data will be divided into lots of small area blocks base on Quadtree, and give a buffer to every block edge, then we can decide which block will be switch in or out, according to real time position of the viewpoint. But, the algorithm has two precondition, which show as follow: One is that the viewpoint can only go forward or back ground-based once the routine is selected, not high-flying; The other is the terrain data should be distributed like strip.

3.1 Buffer-Quadtree

How to divide the data block can improve the work efficient, in this paper, the terrain data block will be organized based on Quadtree. Figure 5 is the representation of general Quadtree, however, in order to make the operation convenient, the Quadtree was predigested as Figure 6, by stipulating the least size of data block. Then we can save the every data block code and their topo-relation using an appropriate structure.

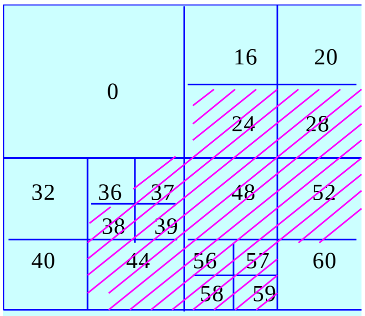

Figure 5. decimal Morton code[1]

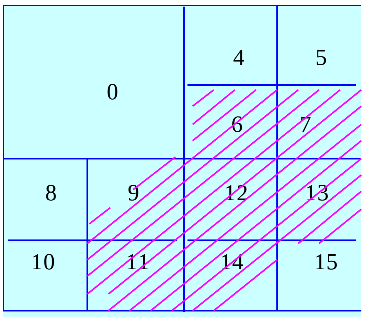

Figure 6. predigest Morton code

And giving an appropriate width, we can form the buffer to every block edge, such as block 11 (Figure 7). According to the code and its topo-relation, we can infer the corresponding coordinates of four square's corner and the adjacent block.

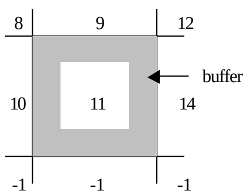

Figure 7. block's buffer

So we can get those triangles, which fall into a certain data block by calculating the triangle's center point 2D(x y) coordinate, and save them. So, when the viewpoint walk on the terrain, we can real-time examine the viewpoint arrive in which data block, and know what blocks will be rendered. Once the block determined, and the buffer width is given, we can infer the current corresponding buffer code.

According to viewpoint and the next node on the roam routine(Figure 8). The width can be adjusted freely, and till it meet the roam velocity of what you need. A general rule for setting initial buffer width is to make the next data block switch in fluently, have no popping. It needs compromise between velocity and memory.

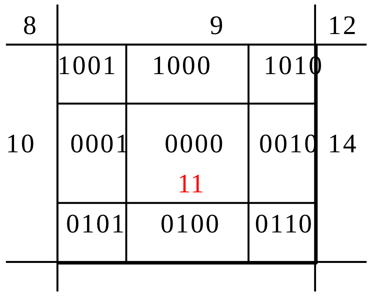

Figure 8. Buffer code of the block 11

3.2 Multi-thread

Once we get the buffer code in one block, we can get to know which block's data will be set. In order to do this, multi-thread technology was used. That is to say, we should apply one thread to detect which block the viewpoint fall in real time, and another thread will be used to upload or release data block dynamically, and a main thread is used to render the scene. For example, if viewpoint is detected fall in block 11, and we calculate the buffer code is 1010, then, those data blocks of 9, 12 and 14 will be read by one thread, then copy the data block to the main thread, and the data in block 10 or others will be released at the same time. So the memory was dynamic allocated and set free, some memory was saved, and the roaming was improved.

4. EXPERIMENT AND CONCLUSION

Base on the algorithm introduced above, we have developed a software called "VirtualWay" using VC++6.0 and OpenGL, it main includes five function module, in turn, these are data in/out module, modeling module, 2D edit module, 3D landscape roam module and 3D spatial operation module. Figure 8 is a case of using "VirtualWay", the terrain's data is simulated.

In recent years, more and more 3D landscape application in the field of communication, in this paper, data model and structure of the 3D road, which is constructed by CDT and integrated with terrain model, and the method of judging the maximum angle was used to eliminate the distortion triangles on these boundary nodes; and how to improve the roam velocity in 3D landscape is a hot topic in recent literature, like surface simplified models. To strip distributed terrain data, a brief algorithm called Buffer-Quadtree, which introduced in this paper can improve the roam efficiency, even the Lod and multiresolution technology wouldn't be used. But, it does not work well if the terrain not like band shape or the viewpoint not walk ground-based, then some other methods look forward to be explored.

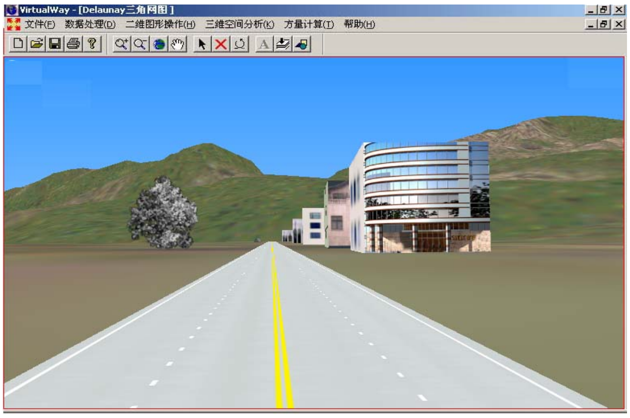

Figure 9. Landscape roaming in VirtualWay

Future work

1). Improve the “VirtualWay” software, by enriching the modeling ways for more irregular complex subordinations;
2). Find a way which the “VirtualWay” can integrate with ITS (Intelligent Transportation System), and make it work more effectively.

5. ACKNOWLEDGEMENT

The work is funded from National Natural Science Foundation of China (No.69833010).

6. REFERENCES

[1] Gong jianya. 2001 *The Foundation of Geographical Information System,* Science press, pp. (in chinese)
[2] Hoppe, Hughes. *Progressive Meshes,* Computer Graphics, Vol. 30 (SIGGRAPH 96).
[3] Hoppe, Hughes. *View-Dependent Refinement of Progressive Meshes*, Computer Graphics, Vol.31 (SIGGRAPH,97).
[4] Jiaqing ZHENG. Xi’an ZHAO, Chujiang CHEN. *MODELING AND LANDSCAPE OF HIGHWAY CAD*, GEOINFORMATICS & DMGIS’2001, Bangkok, May 23-25, 2001, 396~398
[5] Jin ZHANG, *Multiresolution Terrain Model*, GEOINFORMATICS & DMGIS’2001, Bangkok, May 23-25, 2001, 364~373.
[6] SUN Min, CHEN Jun, *Research on Data Modeling for 3D Landscape Entities Based on Geometry Primitives*, Journal of Wuhan Technical University of Surveying and Mapping Vol. 25 No.3 June 2000 (in chinese).
[7] Zhu Qing, Chen Chujiang, *Quick Generation of TIN and Its dynamic Updating*, Journal of Wuhan Technical University of Surveying and Mapping, Vol.23 No.3 Sept.1998 (in Chinese).