Transect-Based Three-Dimensional Road Modeling and Visualization

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ABSTRACT

With the rapid development of 3D GIS, especially Computer Graphics，Simulation and Virtual Reality, 3D GIS is applied in many fields (Li Deren, 2000). On the base of study the road elements and the existing three-dimensional road data model, such as the standard road flight in the MultiGen Creator and the TIN-based partition model(Chen Jun, Sun Min, 1999), the authors put forward the transect -based road modeling, resolve the modeling of the simplest road with two road transects, and fulfil the visualization of the road. OpenGL is applied as the tools of visualization. The map texture technology、LOD algorithm、dynamic multi-differentiating texture technology are of benefit to the construction of 3D road GIS, and improve the speed of roaming and effective visualization. The authors study the combination of the 2D road digital map and 3D road scene, and the dynamic response between 2D road digital map and 3D road scene.

Finally, base on the research of the transect-based road model, The authors develop the three-dimensional road geographic information system called Virtual Road (VRoad), The VRoad does not only supply for road designer a set of tool which can turn the designed 2-dimensional road data into three-dimensional road and the high road assistant function area in computer, but also supplies for the road management a set of tool which can realize the road real time and interactive roaming, high-efficiency management.

KEY WORDS: 3DGIS, Road modeling, Virtual Reality, LOD

1. INTRODUCTION

Road plays very important role in the human activities. If there are no roads, we can't imagine what the world be. With the rapid development in construction of transportation in China, more and more roads have already been running or will be going to run, The Ministry of Communications of China claims that Chinese road length is the forth longest all of the world. Therefore, the more optimizing-ways are demanded to improve the road surveying, planning, designing, constructing and efficient managing.

With the rapid development of three-Dimensional Geographical Information System (3DGIS), especially Computer Graphics，Simulation and Virtual Reality, 3DGIS is applied in many fields, including the road designing and construction. But the road design and management are so complex that 3DGIS is applied in a limited task of the road construction. 3DGIS enable the road designers to make collaborative and interactive design, and provide a tool for the design group to explore many "what if" situations quickly, and turn the real-time interactive road design into the work.

Virtual reality applications in road design show great potential. For example, complicated road designs can be modeled and tested in a virtual environment before construction. VR applications can improve the constructability and maintainability of roads and bridges, and also be used by designers and builders to better plan and schedule road and bridge maintenance operations and efficient management. The road three-dimensional Geographical Information System can simulate the landscape of the road. During the road driver testing and research, many applications have been developed to evaluate driver response and the road designing performance in computer-generated environments, which make the road designers modify their thinking, optimize their designing, which also enable the department of the road management to improve their managing pattern and improve the efficiency of management.

2. MODELING OF ROAD

The modeling of road elements is the base and precondition of road visualization and construction of the road three-dimensional system.

2.1 The Road Elements

Road elements include terrain, road surfaces, road center greenbelt, roadbed, road ditch, road counterfort, road auxiliaries (such as road lamp, guidepost, road fencing, road outline sign), the buildings (such as gas station, repair bay, dining-room, restaurant, toilet, park), traffic sign (such as road drive way line), road scene (such as sky, road tree, grass)and so on (Figure 1).

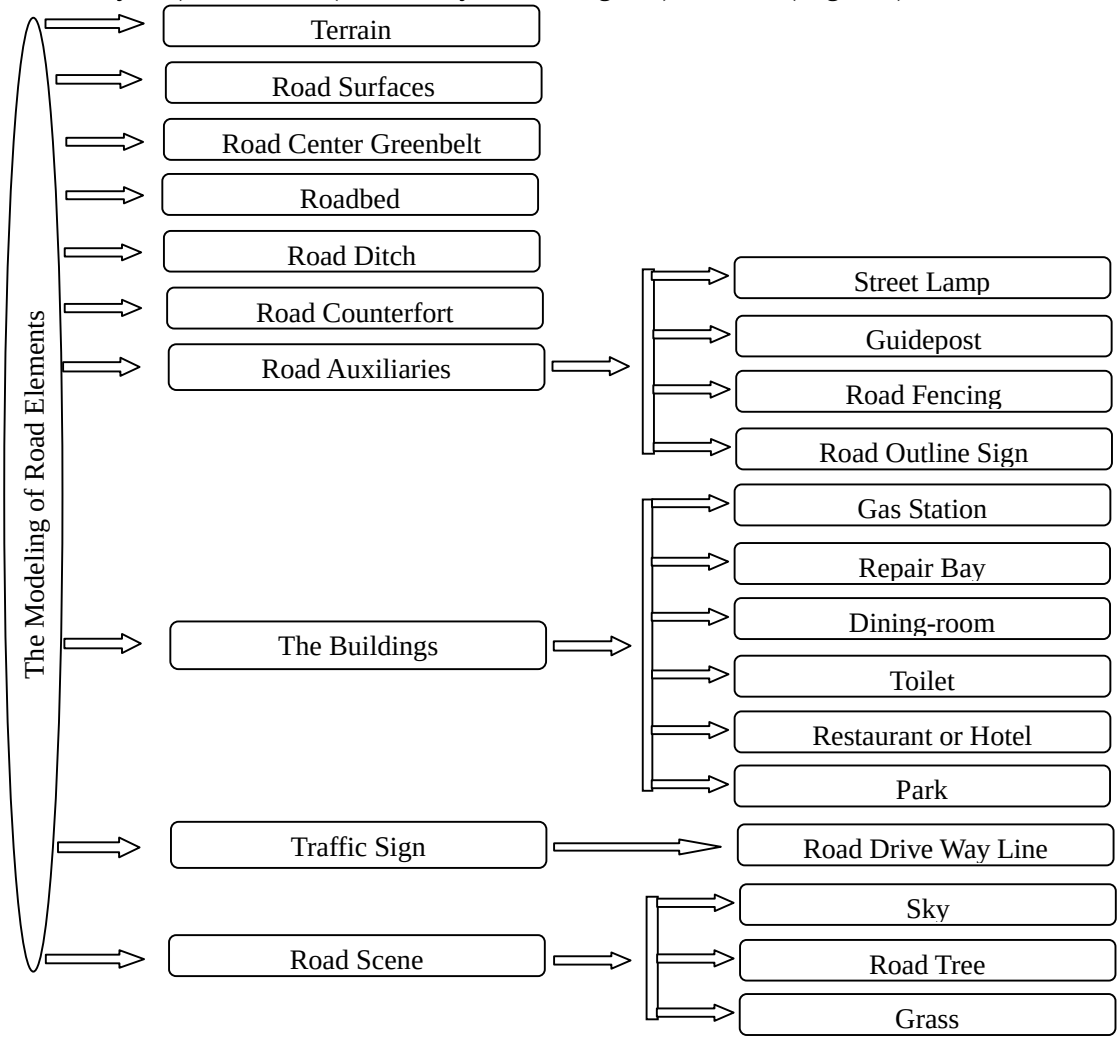

Figure 1. The Modeling of Road Elements

2.2 The Road Data model and Structure

3DGIS data model and data structure are the most important to express the three-dimensional entities. Many researchers of the world who work in the GIS domain have being done lots of studies, and progresses has been made, for example, a surface-based model, such as grid, shape and NURBS (Harbaugh and Merriam, 1968); A volume-based model, such as Octree, Construction Solid Geometry (CSG) (Samet, 1990),TEN model (Pilouk 1994, Oosterom 1995, Chen 1995, Li Qingquan 1998); an integration of a volume-based and a surface-based model, Examples of hybrid models include the integrated CSG and Octree model (Li, 1994), the integrated TIN and Octree model (Shi, 1996), and the integrated TEN and Octree model (Li, 1996); An object-oriented 3D GIS model (Yang Bisheng, 2002).

Due to the road complication, there are many researchers put forward lots of road data model and road structure. The road flight is applied to express the road in the MultiGen Creator, in which if the road center line is set, the road will be created with standard road flight, the road surface is on the same height, the higher outside in the road crankle can't be expressed (Figure 2). A based on TIN partition model (Figure 3) is put forward to express the road (Sun Min, 2000). MultiGen Creator and based on TIN partition model can't express the road ditch, roadbed, road counterfort, and road auxiliaries etc.

Figure 2. The road expressed in MultiGen Creator

Figure 3. The road expressed by based on TIN partition model

2.3 Transect-based Road Model

Based on the study of the road model, the author put forward to a new road model to express the three-dimensional road in the computer. This model is based on the road transect, and the road is composited by many transects. The simplest road that is defined a road flight is composited by two transects, the road standard transect and defines are expressed in figure 4.

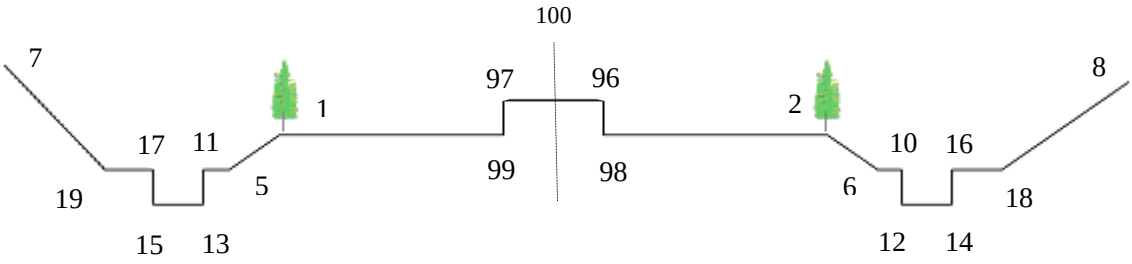

Figure 4. The Road standard transect and the road elements sign

The road elements sign are defined as follow:

100 stands for road center point, 99-100 and 98-100 stand for road center greenbelt, 1-99 and 2-98 stand for left and right road surfaces respectively, 5-1 and 6-2 stand for left and right roadbed respectively, 17-11 and 16-10 stand for left and right road ditch respectively, 7-19 and 8-18 stand for left and right road counterfort respectively.

The transect-based road model has a powerful potential, the roadbed, road ditch, road counterfort are all expressed in the transect. The road transect can change if there is no road ditch or no counterfort in the course of road design. The road will be finished as long as the road center line and the road transects are set.

2.4 The Modeling of the Road with the Transect-based Model

2.4.1 The Road Center Line Data and the Azimuth Angle

The road center line is a very important character of a road. Once the road center line is set, the road line form is determined. In general, the road center line is defined as stake: KA±B (A and B stand for the distance).The azimuth is define as the horizontal angle of the road transect's bearing in surveying, measured clockwise from a referent direction as from the north.

Road stake structure is defined as follow:

```
typedef struct {
        float stake;        //the distance of road center point to the beginning
        POINT3D pt;         //the center point, including x, y, z
        double angle;       //the azimuth angle of transect which lies in this stake
}Stake;
```

Road center line is composited by many stakes, and it is defined as follow:

```
CArray< Stake, Stake >RoadCenterLineArray      //the road center line
```

2.4.2 The Road Transect Data and Structure

In general, the road transect character points such as 1 in the transect are defined as the number sign, the distance from this point to the road center point 100, and the height. The road transect character points are defined as follow:

```
typedef struct tagTranPoint{
    int id;              //the road transect character point number sign
    double dist;         //the distance from this point to the road center point 100
    doubel height;       //the height
}TranPoint;
```

The road transect is composited by the stake number, and the transect character point array, which is defined as follow:

```
typedef struct tagRoadTransect{
    float stake;                                          //the transect stake
    CArray< TranPoint, TranPoint >TranPointArray;      //the road transect character point array
}RoadTransect;
```

2.4.3 The Modeling of Road

The transect-based road model is applied to the modeling of road, the road designer can plan the road line form according to the terrain, the road land use, and the road line style. The road stake can choose 20 meter distance where the road transect change less, otherwise the stake distance can be shorten, and the road transects are added.

The same ID character point on border upon transects are linked, and make the triangle partition (Figure 5). If there is the ID character point on the one of the transects, and there is not the same ID character point on the other transect, this ID character point will be linked to the less distance character point on the other transect.

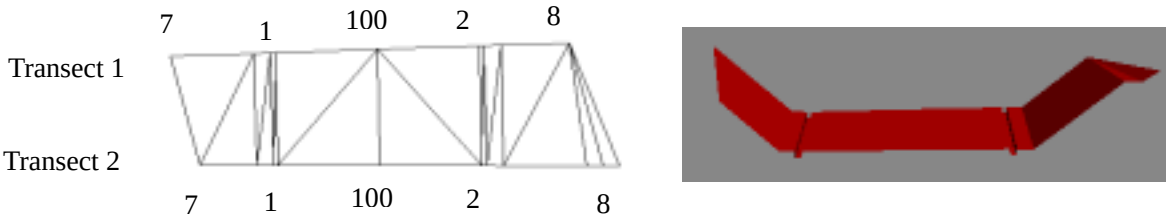

Figure 5. A Simplest Road Made up of Two Transects

3. THE VISUALIZATION OF THE ROAD

OpenGL is applied as the visualization tool of the road. OpenGL is a software interface to graphics hardware. This interface consists of about 120 distinct commands, which you use to specify the objects and operations needed to produce interactive three-dimensional applications. OpenGL is designed to work efficiently even if the computer that displays the graphics you create isn't the computer that runs your graphics program. OpenGL is designed as a streamlined, hardware-independent interface to be implemented on many different hardware platforms. To achieve these qualities, no commands for performing windowing tasks or obtaining user input are included in OpenGL, instead, you must work through whatever windows system controls the particular hardware you're using. Similarly, OpenGL doesn't provide high-level commands for describing models of three-dimensional objects. Such commands might allow you to specify relatively complicated shapes such as automobiles, parts of the body, airplanes, or molecules. With OpenGL, you must build up your desired model from a small set of geometric primitive-points, lines, and polygons.

The visualization of the road is that the modeling of the road elements are visualized with OpenGL. The map texture technology can improve the simulation vision, the different road elements will be mapped different texture. Level of Detail (LOD) algorithm can improve the speed of the road roam, and effective visualization.

4. THREE-DIMENSIONAL ROAD SYSTEM, VIRTUAL ROAD (VROAD)

Based on the study of the transect-based road model, a three-dimensional road system called Virtual Road (VRoad) has been developed by using VC^{++} 6.0 and OpenGL. VRoad mainly includes two parties: two-dimensional road map and three-dimensional road scene. It includes four function module, which are data import/output module, road modeling module, 2D map module, 3D road landscape roam module. VRoad can fulfil an interactive response in the 2D road map and the 3D road scene, when roaming run to a place in the road 3D scene, the navigator will display the place in the 2D map, which is an integration that the 2D map’s through virtue and the 3D scene’s party virtue (figure 6).

Figure 6. The VRoad expressed by transect-based road model

5. CONCLUSION

The road three-dimensional model is important to express the road, and choosing a good road

model is the key of a system construction. The transect-based road model is put forward to express what the modeling of road elements demand, but there are many questions need to be resolved, such as how to make a integration of the road models with terrain, and how to resolve the large volume data.

6. ACKNOWLEDGEMENT

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