Multi-Scale Data Organization and Management of 3D Moving Objects Based on GIS

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Abstract. How to describe 3D moving objects motion model of good adaptability, how to present and store moving objects data in the database and realize the self-adaptive dynamic visualization of 3D moving objects with positioning and communication information, are the key problems on data organization and management of 3D moving objects. The information about 3D moving objects are references with the location and time, including the real time geographic information. This paper proposes a new method of multi-scale data organization and management of 3D moving objects based on GIS. The 3D-terrain is rendered with triangle subdivision bi-tree data structure and LOD, which are easy to realize the rapid visualization for 3D moving objects. The experiments show that the proposed method is suitable to 3D moving objects in large-scale complex virtual environments.

Keywords: Data organization, Moving objects, GIS, Multi-scale

1. Introduction

With the development of the wireless communication technology, space positioning technology, GIS and the actual demand increased, the information management of geographic objects is changed from static to dynamic gradually. Especially, more and more people pay attention to moving objects in real 3D scene (Mendoza C & O'Sullivan C 2006, Stefanik K V et al. 2011). The data organization, management and visualization technology fit the demand of the information age. So it succeeded in many fields such as emergency services, the plane/ship/vehicle navigation, intelligent transportation, electronic battlefield, public security, logistics management, e-

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commerce, search and rescue, travelers' service and other kinds of LBS service and so on. All the services are dependent on the efficient organization management of moving objects. Moving objects are the running main body of moving computing environment, how to implement the efficient management of moving objects will become a hot spot in this research field (Güting R H et al. 2011, Kuijpers B & Othman W 2010).

Sistla et al. put forward the concept of moving objects for the first time in 1997 (Kuijpers B & Othman W 2010, Kwon D et al. 2006). Then many scholars proposed the different moving objects motion model. Spatiotemporal Snapshot Model, Base State and Amendment Model, Spatiotemporal Composite Model, Spatiotemporal Cube Model, and Spatiotemporal Object Model are some of the most common models (Erwig M & Schneider M 2002).The abovementioned traditional spatiotemporal data models are more suitable for space object with time changes in discrete modeling, which is difficult for the moving objects of continuous movement. Many researchers extended the dynamic properties of moving objects to the spatial data models. Wolfson and his study group from the university of Illinois at Chicago proposed the MOST model (Kuijpers B & Othman W 2010). Forlizzi et al. form the Italian Aquila university proposed discrete data mode (Cho H et al. 2004, Chang J W et al. 2010).

Each model has its own characteristics, scope and restrictions. How to combine the characteristics of multi-scale data, expand the content of models, produce the moving objects motion model with better adaptability based on these models are very necessary. Synthetically considering 3D moving objects motion model, the index mechanism, collision detection, terrain matching and adaptive visualization method and other factors, making moving objects data scheduling, self-adaptive and draw such links as a whole process, this paper puts forward the multi-scale data organization and management methods of 3D moving objects based on GIS.

2. Improved MOST model

2.1. The entity data structure of moving objects

Combined with the multi-scale concept of moving objects data, the storage way of the moving objects data in the database is designed. The entities of moving objects includes: identification of moving objects, position of moving objects, attitude of moving objects, velocity vector of moving objects, sports mode, time, additional information, current status and verify information and so on. As shown in Fig.1, the entity data structure is easy to support the simulation of flexible motion function and the storage management of movement position of moving objects.

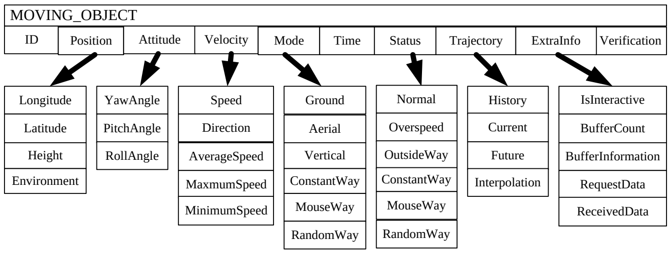

Figure 1. The entity data structure of moving objects.

Identification of moving objects is the only identifier of a moving object. Position of moving objects is its corresponding space position information. The position relating to the earth coordinate system can be longitude or latitude, and also can coordinate the coordinates of the earth or other forms. Attitude of moving objects is a moving objects 3D model in the three dimensional scene attitude of information. Velocity vector can be a function of time (linear function or other functions). As the weight of the speed, the velocity vector mainly includes current speed, moving direction, average speed, maximum speed, minimum speed and other information. Moving mode is decided by the nature of the moving objects in three dimensional scene, including ground motion, aerial motion, vertical up-and-down motion, constant way motion, mouse way control motion, random way motion and other ways. Time is the information that is relevant to the current position of moving objects. Moving status reflects the running situation of the current moving objects, including normal motion, over speed motion, outside way motion, constant way motion, mouse way control motion, random way motion and other information. Moving trajectory reflects the path information of the moving objects, including history trajectory, current trajectory, future trajectory and interpolation function, etc.. Extra information refers to the additional information of the moving objects. Verification is to ensure the integrity of the moving objects data.

2.2. 3D path interpolation algorithms

In 3D moving objects trajectory, in order to ensure terrain ups and downs with the movement of the moving objects, the interpolation function is not only required " through points", namely interpolation function and inserted function in the point have the same function value, but also required "tangency", that is the point where both have the same derivative value (Tsang L M et al. 2011, Wu J et al. 2010, Gao Y et al. 2010, Brown E R et al. 2005). 3D path interpolation is first using the derivative coefficient matrix of B spline curve to build the finite element equations, deleting some 3D path mutations points of the tracks. And then using the three times Hermite interpolation to create the initial path of moving objects, going on collision detection for moving objects, using terrain matching algorithm to accurate calculate place names point coordinates of a moving objects' track, namely getting 3D trajectory of the moving objects. The flow chart is shown below:

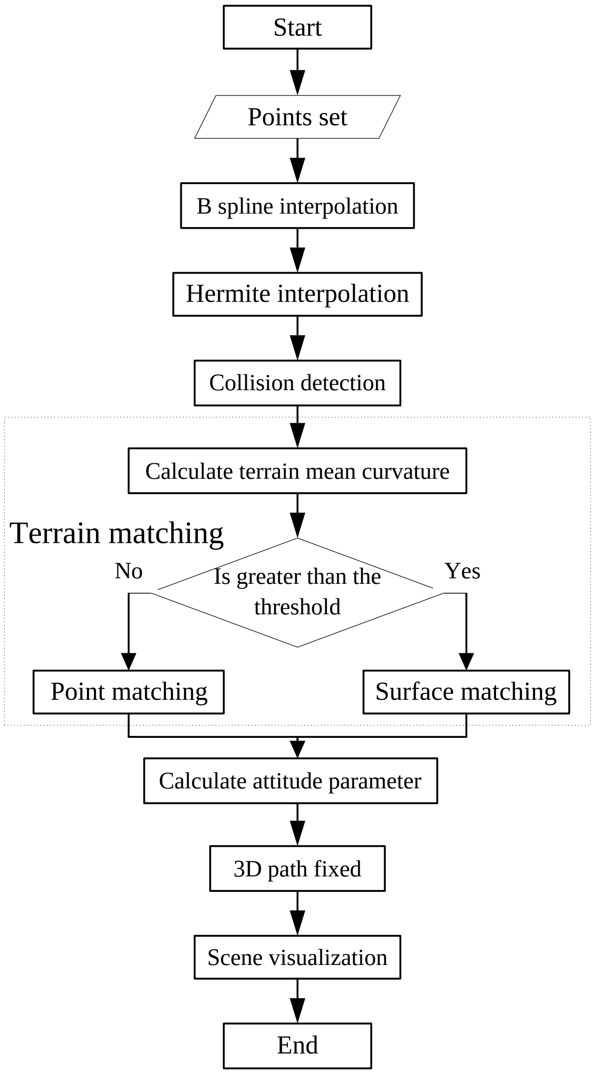

Figure 2. 3D path interpolation algorithms.

(1) Denoising of the location points sparse. Because of the complexity of moving objects data collection, the anchor points have some errors inevita-

bly. So it needs to use three times B spline curve approximate fitting to these anchor point, and to delete 3D path mutations point in some of the tracks;

（2）Creating the initial path of moving objects. Using three times Hermite interpolation function simulation to create moving objects initial path;

（3）Constructing the bounding box of the moving objects. Using slightly higher than the volume and geometric characteristics of simple bounding box to approximately describe the complex moving objects, and then through structuring tree structure to approximate geometric model of the moving objects;

（4）Establishing LOD terrain grid. Through recursion division of the triangle binary tree to form the adaptive, seamless LOD grid;

（5）Collision detection of the moving objects. Carrying the bounding box and terrain grid on intersection test to determine whether a moving objects and the terrain contact;

（6）Terrain matching of the moving objects. Calculating terrain mean curvature, when moving objects are less volume than the terrain of triangles, using the single point matching method, for the other case, using the surface matching method;

（7）Calculating attitude parameter of the moving objects. The initial path is revised to carry on visualization of moving objects in 3D scene.

3. Rapid visualization of the moving objects

The rapid visualization of a large number of moving objects in 3D scene still suffers serious constraints by moving complexity and the number of the objects model. Such as Vega of Multigen, ArcView 3D Analyst of ESRI, DILAS of Geonova, the popular general commercial software platform for performance of the moving objects at present have done some work, but still can't meet the goal of the moving geography synchronous processing demand (Stefanik K V et al. 2011, Chen-guang D & Xue-qing D 2007). It is needed to make intensive studies especially in the classification of the moving objects, the design of the data model and the data structure, and LOD (Wu J et al. 2010, Lambers M & Kolb A 2010, Kang L et al. 2010).

To the data management and access level in the 3D geographic information service, this paper is based on the pyramid grid/image management method which is the common use of the current mass 3D terrain visualization system. It sets up simplified segmentation, organizational management and index scheduling method of vector data on the basis of this frame, to ensure rapid scheduling of vector data and the data of the grid under the uniform space reference and index framework. The flowchart is shown below:

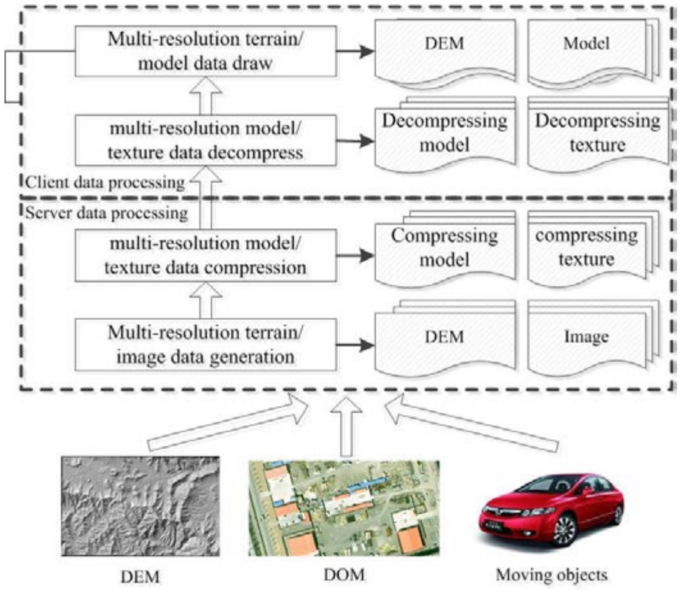

Figure 3. 3D visualization process based on LOD.

4. Experimental results

In order to evaluate the actual performance of our proposed method, we implemented the method in Visual C# language under Windows 7 on a PC. The system is developed based on improved MOST model, 3D path interpolation algorithms and rapid visualization of moving objects discussed above. It works as a group of automation module, providing information management of 3d moving objects' motion data and attributes including categories of objects. The main functions include management of 3D moving objects model, management of motion state, management of objects' trajectory, spatiotemporal query, continues query, roaming and so on.

A moving vehicle is shown in Fig.4. The red lines are the objects' trajectories. The movement path is interpolated based on the discrete points and the 3D vehicles are loaded in the 3D terrain scene. In the 3D scene vehicle models follow the path of 3D movement to be automatic moving, realizing visualization of the moving objects. In Fig.5, the vehicles detailed information of movement path in 3D scene are shown. In Fig.6, the inquiring 3D path information of the vehicles, including time, latitude, longitude, elevation and other information are shown. The experiments show that the proposed algorithm is suitable to 3D moving geographic objects.

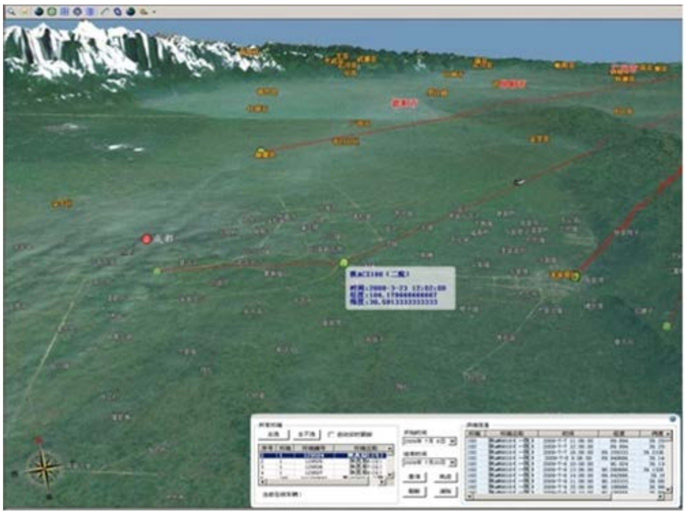

Figure 4. Visualization of the vehicles in 3D scene.

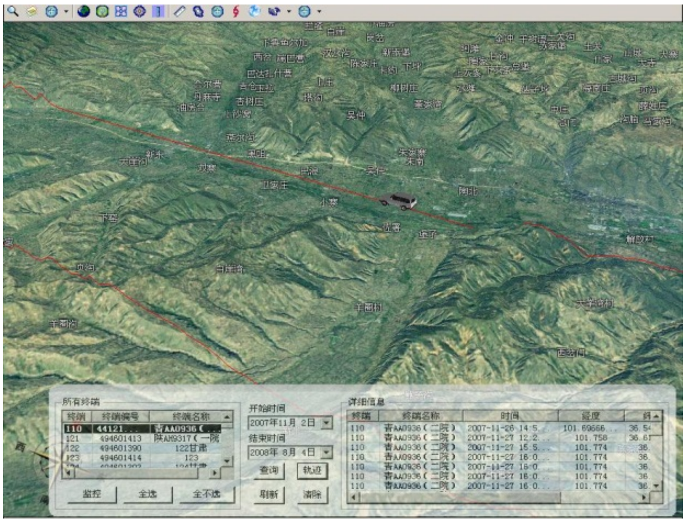

Figure 5. The vehicles information of the path.

Figure 6. Inquiring the path information of the vehicle.

5. Conclusion

This paper proposes a new method of multi-scale data organization and management of 3D moving objects based on GIS, which could create high reality of 3D moving geographic objects simulative motion in the virtual environment. This paper renders the 3D-terrain with triangle subdivision bi-tree data structure and LOD, which are easy to realize the rapid visualization for 3D moving objects. The method in this paper provides great theoretical value and practical meaning to visualization of 3D moving objects in large-scale complex virtual environments.

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