Research on Adaptive Triangular Irregular Network for Virtual Battlefield Terrain

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***Abstract*—Constructing virtual battlefield terrain is a very important subject in military simulation. In allusion to the shortcoming of actual triangulated irregular network, an adaptive triangular irregular network is proposed in this paper, and the 3D modeling of the battlefield terrain is built. Effectiveness and speediness of the proposed method was demonstrated by the experiment result, and the details and precision of terrain mode1 is better than others.**

Keywords-Virtual Battlefield Terrain; TIN; Shepard interpolation

I. INTRODUCTION

Based on visualization and command automation, battlefield information visualization technology is developing at very fast speed, which will be inescapable in the future war. The common battlefield situation system is the combination of the integrated information platform of space state and visualization system, which various spatial information, such as military terrain, resources and environment, and the data of situation of war including our army, friendly army and enemy can be saved, searched, analyzed, displayed and outputted, followed by the development of battlefield situation awareness that can be provided for various commander[1]. The three-dimensional battlefield environment is based on battlefield terrain model, which is an important part of virtual battlefield environment. The visual acceptable and accurate geometric details should be produced by the terrain model. Most importantly, the interference for the real terrain to the floor can be simulated and the effects of real terrain on soldiers and performance of weapons platform can be reflected. So the simulation results correction is capable of being guaranteed[2,3]. Because there is such a large battlefield terrain scene, some special tools of are needed to produce terrain model.

So far, many acquirement methods of terrain data have been developed. Fractal algorithm that has introduced the fractal technology to iterate terrain template can improve multilayer terrain detail and generate vivid terrain model. However, it has disadvantages of massive redundancy points and the disturbance of triangular meshes has rift easily after terrain is generated[4]. The data format of the regular grids method is simple, which height detail is rich. But the method has large terrain data size and rendering is slower[5]. The triangulate irregular network (TIN) can approximate geometric height in fewer triangular faces and the resolution can be adjusted. The method enhances rendering speed. But TIN is complex topological structure, huge calculation is needed to construct model. It does not facilitate for large scale real-time terrain romancing in the navigation precision[6]. This paper discusses an adaptive triangulation algorithm based on TIN, which the efficiency of the construction of TIN improved, and its accuracy can be insured.

II. SOLID MODELING OF VIRTUAL BATTLEFIELD ENVIRONMENT

The TIN can be used widely, such as the three-dimensional visualization for the spatial object, cutting of any section, and calculation to slope direction, etc.. In comparison with square grid structure, the geomorphic feature points and lines based TIN can be formed better. Tin may show the complicated topographical deviate degree with great reality and has a variable resolution, that is to say, if the model has a rough surface, TIN is able to contain a huge universe of data points; on the other hand , when the surface is not complicated, TIN requires only the least points[7]. Up till now, many algorithms of automatic generation for the TIN have been done well. However, most of the vertexs of a triangle are the original data points or the feature points of the isoline, so the even degree of the data points is quite different. The spatial distribution of the triangle isn't as even as the grid model. In order to make sure the accuracy of the models, the TIN from different sources should often be handled encryption, which the models are much more approach to the actual situation[8].

The adaptive TIN is needed to minimize user intervention and automatically create the TIN of variable density to meet the requirement. Kang Lin[9] proposed the enveloping triangulated network, which the divide-conquer algorithm is improved. The simulation terrain was separated into 40×10 small rectangular blocks. As the subnets were merged, the generated gap triangle network would be legally decided. In this way the triangles of redundancy are avoided and an envelope net of triangulation suitable for purpose was constructed. But subdividing resolution has great influence on actual effect. In actual use if the appropriate subdividing threshold was not selected according to the actual appearance of terrain, it had a strong effect on the triangulation.

In this paper, a hierarchical grid will be constructed. The shepard interpolation is combined with multi-resolution analysis, which the differential quantities of data point are estimated during the process of grid subdivision, so cells could be increased in densely sampled regions and local features of the model can be preserved well.

A. *Adaptive Shepard interpolation*

KE Ying-lin[10] proposed a curvature estimation based on 4D Shepard surface for estimating the differential quantities of data points $\left\{p_j = \left(x_{p_j}, y_{p_j}, z_{p_j}\right)^T\right\}_{j=1}^{n}$ in point cloud, which the 3D Shepard function was changed as follows:

$$F(x,y,z) = \sum_{j=1}^{N} G_j(x,y,z)\delta_j \Big/ \sum_{j=1}^{N} G_j(x,y,z) \quad (1)$$

where

$$G_j(x,y,z) = d_j^{\mu}, \quad \mu = -2$$

$$d_j = [(x-x_j)^2 + (y-y_j)^2 + (z-z_j)^2]^{1/2}$$

δ_j is the differential quantities.

Because Shepard basic function possesses local smoothing itself, which can effectively suppress noise, but at the same time, it brings bluntness of sharp transitional features. When Shepard interpolation is combined with multi-scale analyses, fisrt each cell is partitioned based on Octree, then near data points are searched base on grid structure, finally the differential quantities of all data points are obtained. The proposed method mades up the defect of the 4D Shepard surface to some extent. The process is as follows:

Step 0. Constructing the level-0 grid from a uniform partition of the bounding box;

Step 1. If the points density of one of cells in the grid is less than a given threshold, taking step 2; or else partition the cell using Octree;

Step 2. For any point $p_j(x_j, y_j, z_j)$ in the point cloud, searching its near point $p(x,y,z)$ based on grid structure, then putting the geometric quantities δ of p and the value of the basis functions into (1), the geometric quantities of p_j is obtained.

B. *Adaptive model for TIN*

Adaptive recognition algorithm for geometric features should be integrated for adaptive model of TIN while triangular meshes are generated, including adaptive curvature feature and adjacent feature. Because the curvature of each point has been found out through shepard interpolation, the adaptive flare angle of curvature feature can be proceeded by user. Then the cell-size of the point is able to be calculated. The adaptive adjacent feature is also computed based on geometric derivative of the point. The adjacent feature distance is calculated based on the excenter of every triangle unit and the radius of its circumscribe. The size of the grid point is namely the adjacent feature distance multiply adjacent adaptive coefficient. The modeling procedure is shown in Figure 1.

Step 0. The data points are preprocessed and the data structure is constructed;

Step 1. The adaptive hierachical grids are generated, and differential quantities of the data points are estimated;

Step 2. The first triangular mesh is created;

Step 3. The error of control model is analysed;

Step 4. To give the tolerance ε; if the error< ε, the new triangular mesh is created; or else, the data structure index is modified;

Step 5. It is made a judgement whether the TIN is completed; if the model has been finished, the process is ended; otherwise it is turned to the third step.

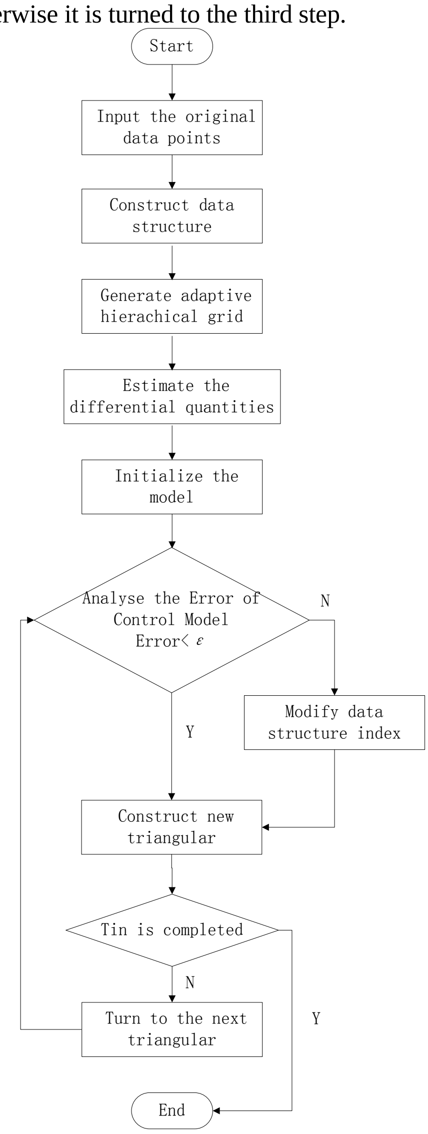
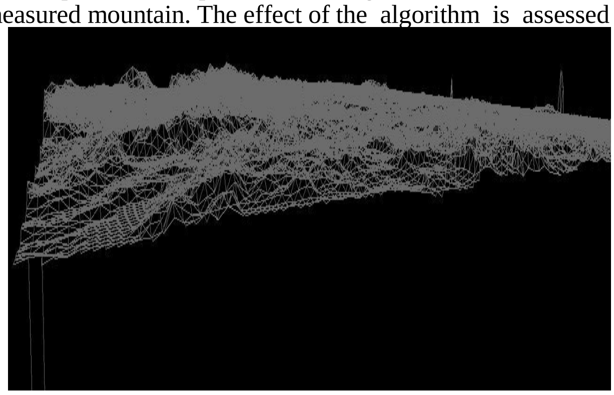


Figure 1. the Modeling flowchart

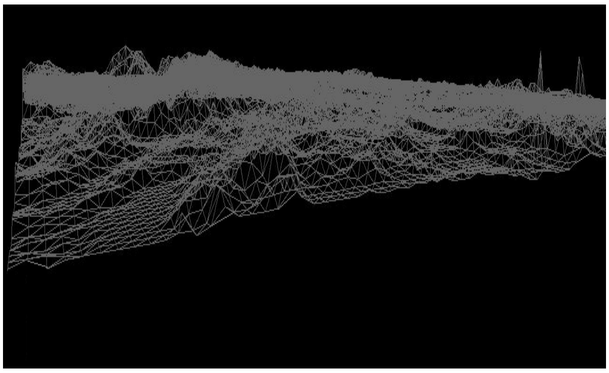
III. IMPLEMENTATION AND EXPERIMENTAL RESULTS

Our algorithm has been implemented using Visual C++ and OpenGL on Microsoft Windows, running on a PC with an Intel P4, and 2.60 GHz processor and 2.0 GB memory. The experiment is performed using the 3D Data of the measured mountain. The effect of the algorithm is assessed by carrying on a contrast analysis of our method and the adaptive envelope TIN, as shown in the Figure 2 and Table 1.

From the Figure 2 and Table 1, we can see that the TIN of Our method is very efficient in applications of three-dimension terrain visualization. The experiment indicates this method has higher precision and practicability.



(a) the Enveloping TIN



(b) the TIN of our method

Figure 2. the TIN of the measured mountain

TABLE I. THE QUALITY DATA OF THE CELLS

Arithmetic	**Minimum angle**	**Maximum angle**	**the Average of minimum angle**	**distribution of minimum angle（%）**			
				0~15	***15~30***	***30~45***	***45~60***
the Enveloping TIN	15.43	165.35	35.29	0.00	9.04	42.31	48.65
Our method	20.27	146.12	43.54	0.00	6.49	38.52	54.99

IV. CONCLUSIONS

Combining Shepard interpolation with multi-scale, our method is effective to solve the bluntness of sharp transitional features, and shows the satisfactory result. It also has adaptive capacity to large scale and complex terrain visualization and the process of TIN model is more automatic. This method provides a powerful tool for commanders who can hold the real-time terrain information of battlefield exactly and rapidly.

REFERENCES

[1] HOU Feng, ZHANG Jun, and LI Guo-hui, “A Summary of the Study on Common Situation of War Information System,” Science of Surveying and Mapping, vol. 32, pp. 17–20, Nov. 2007.

[2] HUPen, SHAO Chen-xi, and YANG Ming, “Conceptual Model Representation of Military Simulation System Based on Qualitative Feedback,” Journal of System Simulation, vol. 20, pp. 449-452, Jan. 2008.

[3] YOU Xiong and WAN Gang, “Battlefield Visualization and Digital Map,” Geomatics World, vol. 2, pp. 19–24, Jun. 2004.

[4] XIA Wei-jie, ZHOU Jian-jiang, and YAO Nan, “Anisotropic Fractal Terrain Generation,” Journal of Image and Graphics, vol. 14, pp. 2356–2361, Nov. 2009.

[5] GUO Tao and PING Xi-jian, “Research on 3D terrain visualization based on OpenGL,” Compmer Engineering and Design, vol. 29, pp. 193–195, Jan. 2008.

[6] SU Yuan-yuan, LIU Jian-dong, and ZHANG Guo-dong, “The Technology of Partitioned Topographic Map Precise Rectification Based on TIN,” Journal of Qingdao University(E&T), vol. 25, pp. 19–23, Mar. 2010.

[7] LIU Ke-wei, LI Xi-bing, and LIU Xi-lin, “3D visualization of complicated cavity group under open-pit limit and its application,” Journal of Central South University(Natural Science), vol. 42, pp. 3118-3124, Oct. 2011.

[8] ZHANG Juan and YANG De-hong, “On TIN Encryption Algorithms,” Market Modernization, vol. 12, pp. 217, Dec. 2010.

[9] KANG Ling, WANG Xue-li, and MING Bo, “Application of 3-D terrain simulation technology in environmental protection dredging engineering,” Journal of Hohai University(Natural Sciences), vol. 36, pp. 670–674, May. 2008.

[10] KE Ying-lin and CHEN Xi, “Efficient curvature estimation based on 4D Shepard surface,” Journa1 of Zhejiang University(Engineering Science), vol. 39, pp. 761–764, Jun. 2005.