Optimized Triangulation Algorithm in Terrain Modeling

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Abstract  3D reconstruction of terrain model based on digital line graphics (DLG) is discussed. An auto-coupling triangles algorithm based on triangle topological relationship is put forward, and the topological data model of complicated terrain is developed. Based on this data model, automatic 3D topological reconstruction of terrain is realized.

Keywords  DLG; DEM; constrained Delaunay triangulation

Introduction

3D terrain model is the digital representation of building terrain surface spatial position and related thematic information, which has been named digital elevation model (DEM) and also been named digital terrain model (DTM). 3D terrain model is the surface reconstruction based on survey data. When the survey data is elevation, it was DEM. The modeling of DEM can be classified into four: based on scatter points, based on triangulation, based on grid and mixed surface. In practice, the modeling methods based on triangulation and grid are frequently used, which have been proved to be two essential modeling methods\cite{1}. The triangle one has good precision, high efficiency and facility of dealing with geo-character, such as rupture line, construction line. So building triangle is the key of building terrain models. Thereinto, because Delaunay triangle has good configuration, and behaves well in represent terrain surface, it has been research and attention focus by so many scholar all along.

1 Data preprocessing

There have many data sources for the reconstruction of 3D terrain model. Aerial photography, light detection and ranging (LIDAR) and digital line graphics(DLG) all can be used. But how to make use of DLG to build DEM is the main direction for cartographers.

In order to ensure the stabilization of the algorithm, data preprocessing of the DLG must be done. Main work for preprocessing the DLG data in experiment area include follows.

1) Delete line feature except contour and elevation point, and make sure that all the feature used for modeling must have elevation information.

2) Extract valley and ridge line as restriction condition of triangulation.

3) Translate contour data into elevation point data.

4) Remain points on the contour which can represent characters of landscape. This can be done by using Douglas algorithm\cite{2} to filter points on contour.

DLG which been preprocessed then becomes points set with elevation information.
2 3D data model of complex terrain

The terrain data model based on TIN is different from the one based on grid. It relies on the correct represent of triangle topological relationship. The paper designs a model for original data and triangulation data on the integrative platform, shown as Fig.1, which has been developed for both data processing and 3D modeling.

![Fig.1  Experiment of constrained Delaunay triangulation](image)

Each triangle, border and node has a corresponding track record. The track record of triangle includes three pointers which record three border of the triangle. The track record of border includes four pointer, two pointers record two conterminous triangles and two pointers record its node. Each node has three value: \(X, Y, Z\). The specialty of this topological triangulation structure is the topological information of triangle, border and node.

A whole original data for triangulation, scattered points, can be described as follows:

```c
typedef struct {
    long x;
    long y;
    long z;
    bool flag;
} TINPOINT
```

Each new triangle created in the modeling process can be described as follows:

```c
typedef struct {
    int no;
    int vertex[3];
} TRIANGLE
```

Array vertex[ ] describe serial number and order of three scattered points which build the triangle. Array neighbor[ ] record serial of triangle which adjoin the triangle in turn.

3 Modeling optimized algorithm based on 3D data model

The flow of modeling optimized algorithm has been shown in Fig.2. Firstly a node array is defined to describe original scattered point data: CArray <CTinPoint*, CTinPoint*> m_aPoints. Then define a triangle array to record triangle created: CArray <CTriangle*, CTriangle*> m_aTriangles.

In Fig.2, variable \(L\) denotes the total number of triangles created by optimized algorithm. When a new triangle is created, \(L\) adds one. Variable \(k\) denotes the serial number of triangle which is expanded in triangle array. When a triangle is expanded completely, \(k\) adds one. Then the next triangle is going to be expanded. Variable \(i\) denotes the serial number of border which is expanded in triangle. Function FindFirstTriangle determines the first triangle and carries through triangle expanding. Function FindNeighborTriangle finds the scattered point which builds a new triangle with the expanding border, and records information of the new triangle. When expanding triangle, valley and ridge line are used, which are extracted by data preprocess, as restriction condition of triangulation. Namely, new triangle can not span valley or ridge line, and valley and ridge line must be used as a border of triangle. Therefore, the problem of 3D reconstruction of terrain can be viewed as a problem how to build scattered points into Delaunay triangulation. The main steps of the optimized algorithm are described as follows.

1) Preprocess data and create new scattered points with elevation information.

2) Find three points to build the first triangle in scattered points, and sign the first triangle as No.1, then put the triangle into the triangle array.

3) Confirm the first border of triangle to be expanded.
4) Choose expanding candidate points from scattered points, make sure that these points stay on the other side of the expanded border with the third node of triangle.

5) Choose the best point from candidate points, and build a new triangle with this point and two nodes of the expanded border. Then put the new triangle into triangle array.

6) If three borders of the expanding triangle have been finished, then turn to Step 7), otherwise turn to Step 3) and repeat perform Step 3) and Step 4) until three borders have been completely finished then turn to Step 7).

7) If there is a triangle in array having not been expanded yet, go to Step 3) and repeat perform Steps 3)-6); otherwise it is clear that all triangles have been expanded complexly. Then the algorithm finish.

When program finished, all triangles in the triangle array have been expanded. At the same time all original scattered points take part in the triangulation process, and finally become the nodes of triangulation, then the reconstruction of terrain model accomplishes. Because every scattered point has an evaluation information, every triangle in triangulations built by scattered points is a spatial triangle feature in fact.

4 Experiment result and analysis

Based on the data model and optimized algorithm of terrain modeling proposed in the paper, we develop an experimental system prototype which realizes the terrain model reconstruction based on digital line map.

In Fig.3, the result of each stage in optimized algorithm of terrain modeling has been shown. The experiment uses contour data source based on digital line map, shown as Fig.3(a); after data preprocessing, scattered points data, shown in Fig.3(b), is extracted and represents the landform characteristic; Delaunay TIN model, shown as Fig.3(c), which is received by optimized algorithm of terrain modeling and proposed data model in this paper; Fig.3(d) represents fill effect of Delaunay TIN model in Visualization process; Fig.3(e) represents phototextured model based on Delaunay TIN in practice.
Many groups of original contour data are used in experiment, and a contrast analysis is got by using two algorithms. The first group of data source has 10,970 elevation points, receives a triangulation with 21,380 triangles. The cost of time is 6 s by original algorithm and 3.8 s by optimized algorithm proposed in this paper. And the second group of data source has 51,380 elevation points, receives a triangulation with 75,160 triangle. The cost of time is 9.3 s by original algorithm and 5.1 s by optimized algorithm proposed in this paper.

Comparing the experiment results of original algorithm and optimized algorithm, it is easy to find that the optimized algorithm proposed in this paper get a distinct enhancement in the triangulation efficiency, and with the spread of triangulation region, the triangulation efficiency of optimized algorithm becomes more and more high. The comparision in triangulation efficient of both two algorithms is shown in Fig.4.

![Fig.4 Contrast of two algorithms](image)

5 Conclusions

The paper proposes a strategy of 3D terrain model reconstruction. Firstly the concept of topology is introduced, which realizes the topological analysis of geometrical relationship of triangles in triangulation. Then 3D data model used for optimized algorithm is introduced. After data preprocess of digital line graphics, the paper realizes the reconstruction of complex terrain model. The next research issue in the future includes the usage of other object in DLG, the special disposal of building footprint, etc.

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