A view-dependent topological LOD model for terrain morphology

Hongbin Wang, Shaoyang Hou, Xinying Zhu, Xuesheng Zhao

College of Geoscience and Surveying Engineering, China University of Mining & Technology (Beijing), D11, Xueyuan Road, Beijing, China, 100083
Telephone: 13810439630
Email: whbcumtb@163.com

1. Introduction

Morphology consists of feature points (pits, peaks and passes), feature lines (like ridges and ravines), or regions with a uniform gradient field. In general, terrain morphological model based on *Morse Complex* has been applied in several applications, such as terrain analysis and understanding, knowledge-based reasoning, and hydrological simulation [Vitali et al. 2012].

A multi-resolution representation of the topology of a height field f is crucial for interactive analysis and exploration of terrains, in order to maintain and analyze their features at different levels of detail (LOD) and reduce the size of their representation. Moreover, a view-dependent topological LOD model is qualified to provide a highly flexible and convenient approach for interactive analysis and exploration of terrain features at different scales with dynamic adjustment of *Complex* complexity according to the distance between viewer and object.

Recently, however, neither hierarchical representation of Morse or Morse-Smale complex [Comic et al. 2012; Danovaro et al. 2007; Bremer et al. 2005] by iteratively applying simplification operators in increasing order of *persistence* presented in [Edelsbrunner et al. 2002] nor a hierarchy of critical net [Danovaro et al. 2006] through a sequence of contraction operators based on the *importance* of the critical-point pairs, can achieve a view-dependent LOD model for terrain morphology because of the importance measurement. More specifically, both *persistence* and *importance* that measure the importance of the pair of critical points p and s to be eliminated, are equal to the absolute difference in function values between them, that is, it can be formulated as follows:

$$W(p)=Abs\{H(p)-H(s)\} \quad (1)$$

Here, $W(p)$ indicates the importance of the pair p and s, and $H(\cdot)$ represents the height value of some point as well as $Abs\{\cdot\}$ the absolute function. As a result, this measurement does not agree with the visual criterion for LOD.

In this paper, a view-dependent criterion that measures the importance of the pair of critical points is established and a LOD model by iteratively applying topological simplification based on this measurement is presented for multi-resolution representation of terrain morphology.

2. Visual criterion in terrain LOD

In the LOD model of terrains, the following two factors mainly affect visual resolution [Xu 2005]:

One is the surface roughness of terrain node. Some approaches, such as the method in

[Jin 2009] for regular square grid (RSG) or calculation of half angle of normal cone (as shown in Figure 1) for triangulated irregular network (TIN), have been presented for the surface roughness of terrain node.

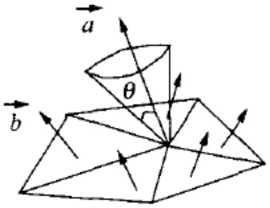


Figure 1 half angle of normal cone

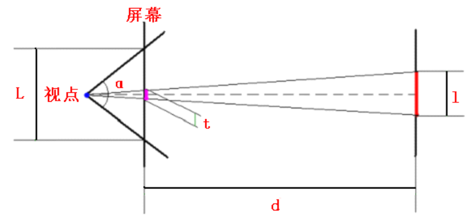


Figure 2 perspective transformation

The other is the distance from viewpoint to object. Essentially, this agrees with the principle of perspective transformation (as shown in Figure 2) and implies the basis of view-dependent criterion.

Consequently, view-dependent error measurement for terrain node can be represented by Formula (2) and can be improved into Formula (3) for higher computational efficiency [Jin 2009]:

$$E(C) = k * \frac{l * L * \lambda}{2 * \tan\frac{\alpha}{2} * D} * f_c \tag{2}$$

$$E(C) \approx \frac{k' * l}{\alpha * D} * f_c \tag{3}$$

Here, k, l, L, λ, α, f_c, k', D suggests a constant, side length of terrain node, the side length of projection screen, the pixel number of unit length projected on screen, the field angle of viewpoint, surface roughness of terrain node, a variable coefficient and the distance from viewer to the center of terrain node respectively.

3. View-dependent topological simplification and LOD

When applying visual criterion discussed above, the corresponding principle can be expressed as follows: in a certain horizon, visible mountains or valleys (corresponding to critical points) will be maintained while invisible ones will be deleted. Moreover, it should be noted that the viewpoint should be located over the terrain model only considering the vertical movement of viewpoint to maintain a global view, with the reason that topology-based method is a global analysis method.

3.1 View-dependent measurement for topological simplification

In *Morse Complexes*, since every 2-cell of *Morse complexes* is not regular and composed of triangles, the specific approach discussed in last section can not be employed directly and some improvements need to be done for the particularity of *Morse* cell in order to be adapted for the general principle of vision represented by Formula (2).

First of all, the surface roughness f_c of a *Morse* cell composed of triangles can be calculated according to the following expression presented by [Tang et al. 2005], which indicates the complexity of regional terrain relief.

$$f_c = \frac{S_{sur}}{S_{pro}} = \frac{\sum S_{tri3D}}{\sum S_{tri2D}} \tag{4}$$

Where S_{tri3D} *and* S_{tri2D} denote surface area and projected area of triangles in a Morse cell.

On the other hand, based on the concept of smallest visible object presented by [Li and Openshaw 1992] or the surrounded-ball measurement generally applied to the view-dependent LOD model of triangulated terrains, diameter (just twice the radius R) of minimum spanning circle which covers the largest contour of a mountain or valley will be acquired to substitute the length l in Formula (2).

Therefore, according to Formula (2), the view-dependent measurement for Morse cell of terrain can be presented as follows:

$$E(C) = \frac{k * R * L * \lambda}{\tan\frac{\alpha}{2} * D} * \frac{\sum S_{tri3D}}{\sum S_{tri2D}} \tag{5}$$

This can be improved into:

$$E(C) \approx \frac{k' * R}{\alpha * D} * \frac{\sum S_{tri3D}}{\sum S_{tri2D}} \tag{6}$$

Here, D denotes the distance from viewer to the center of minimum spanning circle.

3.2 An algorithm for the topological LOD construction

An algorithm for view-dependent topological simplification is developed, and also the reverse of simplification is presented here in order to construct a topological LOD model for terrain morphology. The main steps of the algorithm are as follows:

Step1: Construct ascending and descending Morse complexes respectively after triangulating terrain data set (see [Vitali et al. 2012]);

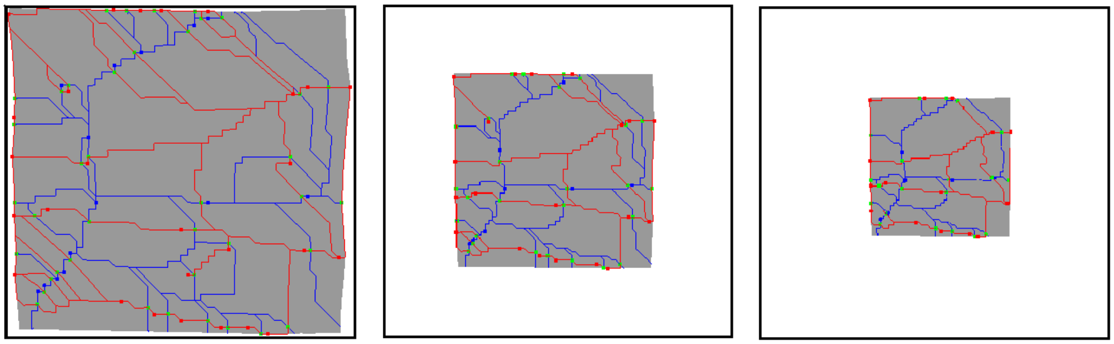
Step2: Calculate center, radius of minimum spanning circle and surface roughness for every Morse cell in the preprocess phase;

Step3: Eliminate those invisible pairs of critical points recursively to construct view-dependent multi-levels of detail for Morse complexes.

4. Experiments and Discussions

The experiments region is selected as Qinghai-Tibet Plateau with the 90m-resolution DEM data from CGIAR-CSI GeoPortal (http://strm.csi.cgiar.org). This experiment includes two-stage process. Above all, the feasibility and efficiency of this topological simplification algorithm is tested. In addition, a hierarchical representation of *Morse Complexes* according to the algorithm presented for topological LOD is achieved and some main parameters are analized.

Figure 3 represents terrain morphology at different scales in our topological LOD model, where the height of viewer is 15000m, 25000m and 35000m respectively. Meanwhile, this process is certainly reverse.



a. H(viewer)=15000m b. H(viewer)=25000m c. H(viewer)=35000m

Figure 3 Terrain morphology at different topological LOD

5. Concluding remarks

In this paper, we firstly present a view-dependent topological LOD model for terrain morphology. This model will provide a highly flexible and convenient interactivity for the terrain analysis at different scales. Some achievements are as followings:

1) A visual criterion is introduced to topological simplification and a view-dependent measurement is proposed for *Morse* cell in order to construct a topological LOD model of terrain morphology;

2) An algorithm is presented for iteratively topological simplification as well as refinement based on the view-dependent criterion;

3) A topological LOD model is finally constructed, in which the LOD operations can be reversed.

6. References

Bremer P T, Pascucci V, Hamann B, 2005, Maximizing adaptivity in hierarchical topological models. In: A.G. Belyaev, A.A. Pasko, M. Spagnuolo (Eds.), *Proceedings of International Conference on Shape Modeling and Applications 2005 (SMI'05)*, IEEE Computer Society Press, Los Alamitos, California, pp. 298-307.

Comic L, Floriani L D, Iuricich F, 2012, Multi-resolution Morse complexes. *Technical report DISI-TR-12-01*. DISI, University of Genova.

Danovaro E, Floriani L D, Papaleo L, and Vitali M, 2006, A multi-resolution representation for terrain morphology. In Proc. Int. Conf. on *Geographic Information Science-GIScience 2006*, Munster, Germany.

Danovaro E, Floriani L D, Vitali M, 2007, Multi-resolution Morse-Smale complexes for terrain modeling. In: *Conference on Image Analysis and Processing*, Modena, Italy.

Edelsbrunner H, Letscher D, and Zomorodian A, 2002, Topological persistence and simplification. *Discrete and Computational Geometry*, 28(4):511-533.

Jin Hailiang, 2009, Research on real-time rendering of massive terrain dataset [M]. *China University of Mining and Technology Press*, 39pp.

Tang Guoan, Liu Xuejun, Lv Guonian, 2005, Principle and method of digital elevation model and geoanalysis [M], *Science Press*, 229pp.

Li Z.,Openshaw S., 1992, Algorithms for Automated Line Generalization Based on a Natural Principle of Objective Generalization. *International Journal of Geographic Information Systems*, Vol. 6, No.5:373-389.

Vitali M, Floriani L D, Magillo P, 2012, Analysis and Comparison of Algorithms for Morse Decompositions on Triangulated Terrains. *Technical report DISI-TR-12-03*. DISI, University of Genova.

Xu Miaozhong, 2005, Research on real-time rendering for large scale terrain [J]. *Geomatics and Informatin Science of Wuhan University*, 30(5):392-395.