Research on Terrain Significance Index and Its Quantification Model based on Grid-DEMs

DONG Youfu
College of Geomatics Engineering
Nanjing University of Technology
No.200 North Zhongshan road, Nanjing, Jiangsu, P.R.C. 210009
E-mail: dongyoufu@163.com

Abstract—***Representing DEM cell's significance in modeling the true terrain surface, Terrain Significance Index (TSI) which refers to the terrain information capacity for a grid point is presented and discussed in this paper by introducing quantitative model, extracting method and applications. On the basis of hierarchical cognitive models of the information theory, a comprehensive quantitative model of TSI is established by measuring local syntactic and global semantic terrain information contents. Choosing a 70km2 area in the loess gully region as test area and 5m-resolution DEM as test data, the paper discussed a series of TSI extraction scheme based on DEMs. In addition, a TSI based application in multi-scale terrain generalization is proposed. Experimental results show that the TSI measurement model proposed is feasible and TSI based multi-scale DEMs construction method is not only easy in implementing but also effective in reducing the terrain distortion. It proves that the multi-scale DEMs constructed by controlling TSI values could meet the demands in different levels of digital terrain modeling. Therefore, the research should be hopeful in deepening our understanding on DEM terrain information characteristics and in building a theoretical foundation and methodological support for multi-scale digital terrain modeling.***

KeyWords—**Digital Elevation Model (DEM), Terrain Significance Index (TSI) , Terrain Modelling, Digital Terrain Analysis**

INTRODUCTION

As we know, a grid DEM expresses terrain information by a lattice data with different elevation values. Meanwhile, it is noticeable that the importance of a set of elevation points representing the true terrain surface in local and global area is markedly different. So, how to recognize and assess the importance of elevation points is of theoretical significance and applied value. There are a lot of criteria to evaluate the importance of elevation points. In general, it shows that the assessment of point importance pays attention to elevation difference in local area but ignores the global terrain skeleton. As a result, it is meaningful to clarify and quantify the importance of elevation points in depth.

METHODS AND PROCEDURES

Methods

The importance of elevation point in modeling the surface is associated with not only elevation variation with the point's grid neighbors but also its topographic position. According to information theory, the importance of elevation point can be expressed by the terrain information of different levels loaded in the point. So, this paper proposes the concept of Terrain Significance Index (TSI) which refers to the importance of elevation points in modeling the terrain surface. And then, TSI is quantified comprehensively from both syntax level and semantic level. The terrain syntax information of elevation point refering to the appearance of terrain variation can be measured by the vector angles of the tangent planes in neighbor grids based on the principle of differential geometry. The terrain semantic information of elevation point refering to the meaning of terrain features is determined by their types and the grades where the point locates in. According to the topographic hierarchy and spatial relationship of terrain features, there are four principles when defining the semantic information of a grid point. The first, each type of terrain features is assigned corresponding semantic information intents; the second, it is independent of the semantic information intents of different terrain features if their spatial locations don't overlay; the third, the semantic information intents of different terrain features such as ridges and peaks are determined further by their geomorphologic characteristics and spatial relations when they coincide in locations; the last, the semantic information intents of the terrain features being the same types and different hierarchies are assigned differentiated weights. The quantification model of terrain significance index is constructed after the measure methods of terrain syntax information and semantic information for a given grid point being established. For the representation of terrain surfaces, terrain feature elements dominate the whole terrain skeleton and the effect is more and more obvious when terrain structure is complicated. To differentiate the grid point importance in depicting terrain and topography effectively, the comprehensive quantification model of terrain significance index is built by overlaying terrain syntax and semantic information values given proper weights.

Procedures

A basin named Jiu Yuangou drainage located in northern Shaanxi province in the Loess Plateau of China is choosed as test area and 5m-grid DEMs produced by State Bureau of Surveying and Mapping of China are used as test data.

Firstly, the extraction programs of terrain semantic information for channels, ridges, shoulder-lines, toe-lines, peak points, pass points, channel junctions and ridge junctions are determined. Then, its terrain significance information index for a grid point is acquired by summing its terrain syntax information value and terrain semantic information value. The extraction results are shown in TSI's spatial distribution map(Figure 1): (1) the grid points locating in terrain skeleton lines are with marked large TSI values and it shows the different levels of landform features well, i.e. terrain structural points, peaks, passes, ridge junctions, channel junctions, ridge points channel points with different orders are of significant variation reflected in TSI value; (2) the grid points where local elevation change sharply are with high TSI value relatively, such as the gird points locating in the microgrooves and the neighborhood relief points in relative flat areas. (3) the TSI values are very low for most of grid points, including flat points and gentle slope points, which indicate that their roles are not important for the terrain representation.

APPLICATION

A TSI based application in constructing multi-scale DEMs is proposed. As we know, the assessment of grid point importance plays an important role for simplifying terrain based on DEMs. So, terrain significance index (TSI) being a comprehensive quantitative index describing the importance of a grid point in modeling the terrain and topography is more meaningful to construct multi-scale DEMs. The procedure of terrain generalization based on TSI is proposed. Firstly, the TSI for each grid points based on high resolution DEMs is extracted. Secondly, candidate terrain points are selected to construct generalized DEMs by setting a TSI tolerance value; Meanwhile, the candidate points clustering are reduced in case of the smaller TSI tolerance. Then, the restricted TINs are established with the last candidate points by joining the terrain feature lines. Finally, the result DEMs is generated by interpolating from the restricted TINs. Because of TSI tolerance influencing the details and precisions of the generalized DEMs markedly by controlling the size of candidate points to construct TINs, the determination of TSI tolerance is the most key step in the whole procedure. In order to determine a most appropriate TSI tolerance for constructing a generalized DEMs being of a terrain detail level, a series of DEMs are reconstructed using different TSI values in the first place(Figure 2); Then, taking the standard 25m-grid resolution DEMs produced by State Bureau of Surveying and Mapping of China as a reference target, the reconstructed DEMs performances are evaluated and contrasted by analyzing the values of their root mean square error (RMSE) and the differences of contour structures. Consequently, the TSI value used to reconstruct DEMs with the relatively best performance is identified as the optimal tolerance.

In evaluating the generalization method for grid DEMs based on TSI, the differences are analyzed by comparing the spatial distribution of the candidate points used to reconstruct the result DEMs, elevation statistical parameters and contour structures taking Very Important Points (VIP) and Three-Dimensional Douglas-Peucker (3DD-P) as verify algorithms and 1:50,000 DEMs as a reconstructed target. Experimental results show that the TSI measurement model proposed is feasible and TSI based multi-scale DEMs construction method is not only easy in implementing but also effective in reducing the terrain distortion. It proves that the multi-scale DEMs constructed by controlling TSI values could meet the demands in different levels of digital terrain modeling. Therefore, the research should be hopeful in deepening our understanding on DEM terrain information characteristics and in building a theoretical foundation and methodological support for multi-scale digital terrain modeling.

REFERENCES

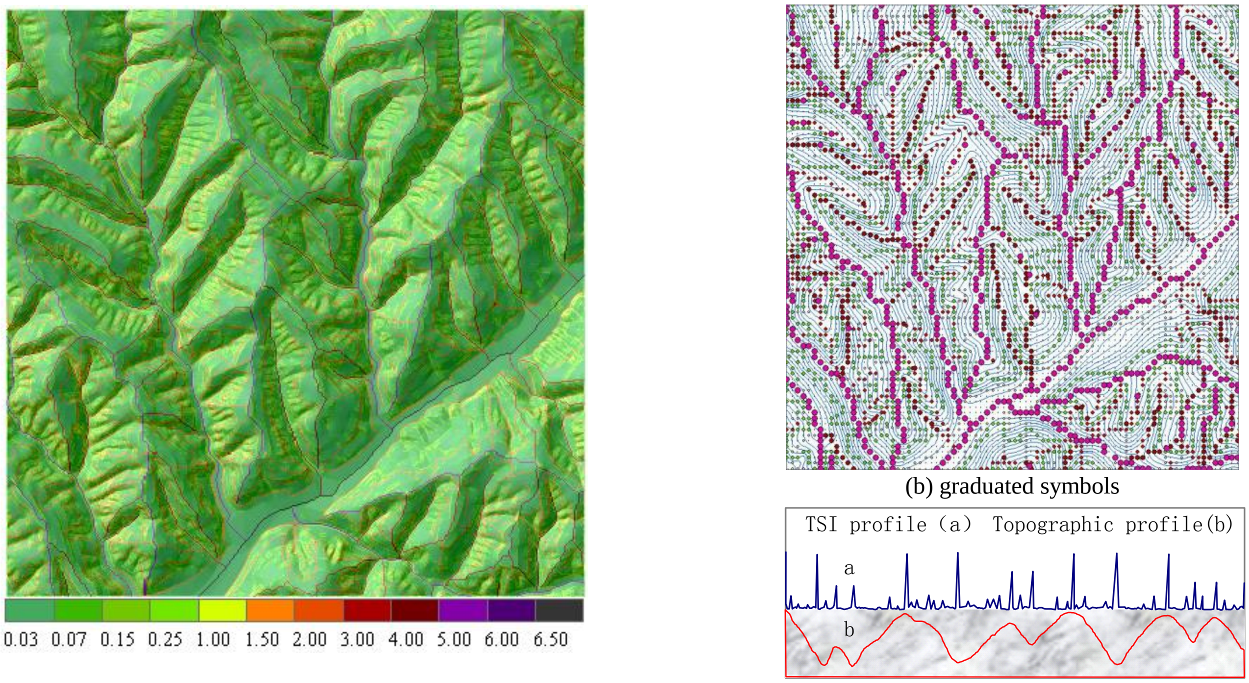
[1] Z.T. Chen and J.A. Guevara,1987, "Systematic selection of very importatn points (VIP) from digital terrain model for constructing triangular irregular nerworks," Proceding of AUTO-CARTO, pp. 50-56.

[2] J.R. Fowler and J.J. Little, 1979. "A utomatic extraction of irregular network digital terrain models," Computer and Graphics, pp. 199-207.

[3] D. Floriani, 1984. "A hierarchical data structure for surface approximation," Computer and Graphics, pp. 475-484.

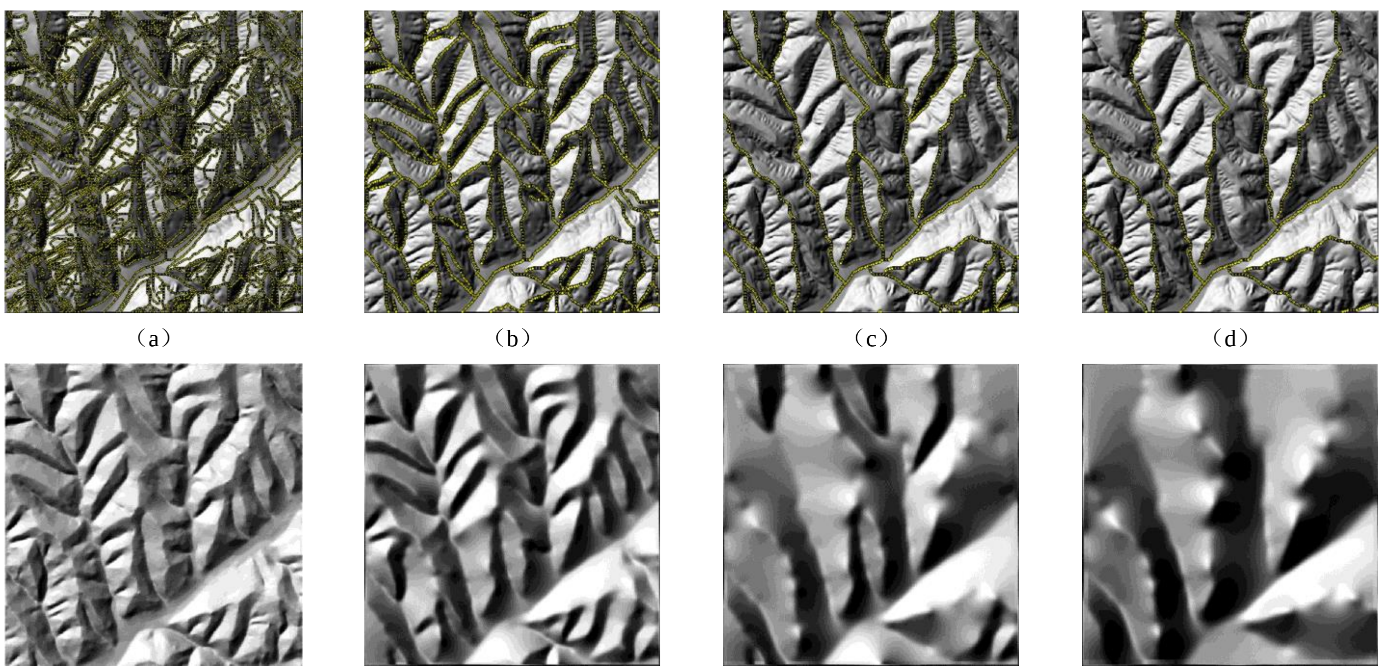
[4] Young, M., 1989. "The Technical Writer's Handbook". Mill Valley, CA: University Science, 325 p.

[5] L.F. Fei and J. He, 2009. "A three-dimensional Douglas-Peucaker algorithm and its application to automated generalization of DEMs," Interntional Journal of Geographical Information Science, pp.703-718.



(a) graduated colors (c) section lines

Figure 1. The extraction results of Terrain Significance Information Index



(e) (f) (g) (h)

Figure 2. The generalized DEMs with different TSI values. (a,b,c,d: the candidate points with TSI tolerance being 1.0,2.0,3.0,4.0 ; e,f,g,h: the generalized DEMs with TSI tolerance being 1.0,2.0,3.0,4.0 correspondingly)