Quantitative Analysis of Terrain Texture from DEMs Based on Grey Level Co-occurrence Matrix

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1. Introduction

Landform morphology is the mostly essential and significant factor among all the geographical elements in representing and modelling of surface process. To a great degree, it determines the basic configuration of material flow and energy conversion on the surface (Panek et al., 2009; McNamara et al., 2006). However, the behaviour of landform morphology is absolutely related to spatial scale. In a micro-scale level, some slope variables, i.e. gradient, aspect, curvature, could represent the basic feature of surface shape and their variation. However, on a macro-scale, terrain texture characteristics are commonly used as a basic foundation in analysis and description of landforms. To be an experienced geographer, a simply glance of a satellite image, the landform types could be judged and identified based on the terrain textural feature such as dendritic textural feature of fluvial landform, side-swing textural feature of loess, plague textural feature of karst landform, corrugate textural feature of aeolian landform and craters textural feature of lunar surface. These landforms reflect terrain morphology characteristics of structural similarity on a certain spatial scale. The mapping of these characteristics on remote image or human vision is called terrain texture.

Textural feature obtained by textural analysis is the important basis in identifying different objects. At present, textural analysis is mainly applied in the field of image processing, Haralick(1973) and Ilea(2011) discussed the concept and connotation of the texture. Some texture analysis methods can be adopted such as statistical texture analysis methods in space domain, structural methods, methods based on model and frequency domain methods which includes power spectrum method, Gabor frequency spectrum method and multi-scale method based on wavelet decomposition. Recently, image textural analysis has been the important basis for object identification and classification.

However, the terrain texture reflected by remote sensing image is actually not the terrain texture in absolute meaning. It is indirectly oriented by the spectral information of objects that over the surface. If the attributes of land-cover are inconsistent such as color and land use, it may cause a lot of trouble for texture based terrain analysis. Hence, an independent information source in representing and analyzing the terrain feature is necessary and indispensable.

Digital elevation models (DEMs), as the major information source in describing surface morphological characteristics, is widely applied in GIS based digital terrain analysis (DTA). Recently, significant achievements have been made in DEM based digital terrain analysis, such as basic theory of DTA, landform morphological characteristic investigation, landform classification and cartography (Anders, et al., 2011; Ian S, 2011). This paper firstly discusses the terrain texture characteristics, then, the Grey Level Co-occurrence Matrix (GLCM), a common textural analysis method, is applied to study the terrain texture of DEMs and its derivatives. At last, some results of DEM based texture analysis and discussions on the applicability of GLCM based terrain texture are given.

2. Materials and Methods

The Construction of GLCM based on DEMs is on the three-dimension curve described by DEM elevation matrix. It regards XOY-plane as a coordinate plane, and then puts forward a series of hypothesis as follows: pixel size equals to r, pixel numbers of horizontal direction equals to Mx, pixel number of vertical direction equals to My, the space domain of horizontal direction is $S_x=\{1, 2, \ldots, M_x\}$, the space domain of vertical direction is $S_y=\{1, 2, \ldots, M_y\}$, z is the elevation coordinate axis.

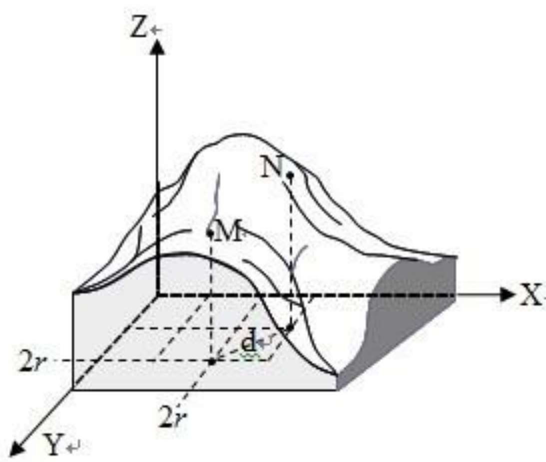
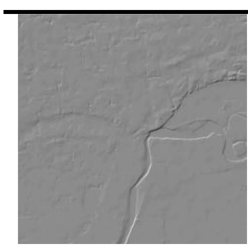
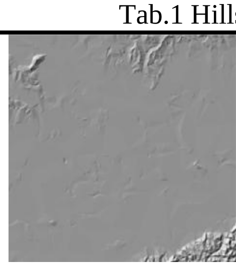
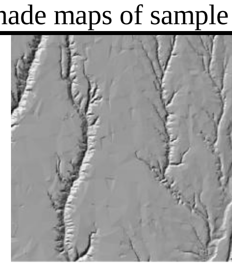
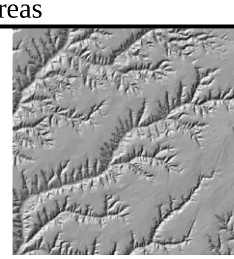
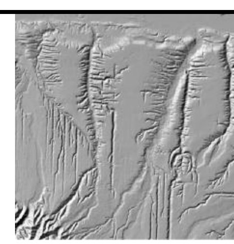


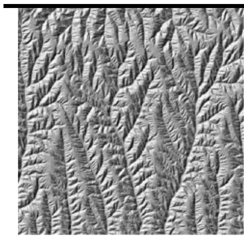
Figure 1 Space expression of dot pair in DEM

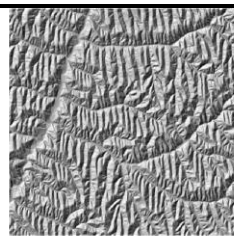
Hypothesizing the distance (project distance) between a pair of pixels equals to d, the direction angle of dot pair equals to θ, then when the direction is parallel with X-axis, θ equals to 0 and counterclockwise rotation around z-axis takes the positive direction. Choose a pair of pixels with direction θ and distance d from texture image and then statistics the joint conditional probability density, then a GLCM model C(d, θ) could be structured. Based on GLCM, Haralick proposed 14 textural features. According to existing research, this paper select 8 features to analysis the terrain characteristics.

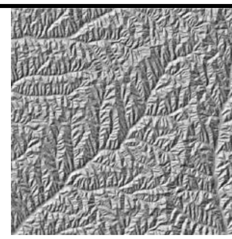
In this paper, 10 sample areas from different landform types of Shaanxi province were selected to make a quantitative analysis. In order to test the feasibility of terrain description and quantization, ideal sample area should be with remarked morphology characteristics and the transitional zones with mixtures of different geomorphology types must be avoided. The range of sample area will greatly influence the stability of experiment result. The analysis range is identified as 10km×10km. The basic morphological characteristics of each sample area are shown in Table one.

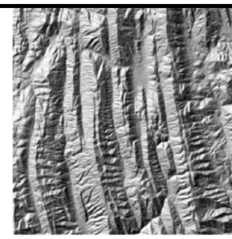
Tab.1 Hillshade maps of sample areas

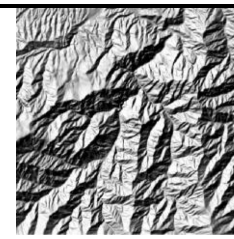
				
Sample Area 1	Sample Area 2	Sample Area 3	Sample Area 4	Sample Area 5


Sample Area 6


Sample Area 7


Sample Area 8


Sample Area 9


Sample Area 10

3. Result

Experiments show that, when using the DEM data with 25m resolution, the suitable analytic distance of GLCM model is not less than 3 pixels. Among all the parameters in the model, correlation could be used for texture direction detection. Contrast, variance, different variance could be applied for texture periodicity analysis. Entropy, angular second moment and inverse different moment are suitable for texture complexity investigation.

In this research, quantitative analysis is conducted to terrain texture by using DEM data, hillshade data, slope data and curvature data. The terrain texture directivity experiment shows that the correlation of hillshade data reacts sensitively to the terrain texture direction and can detect main terrain texture direction. The correlation of slope data reacts obviously in rugged topography such as hilly region and mountainous regions so it can play an auxiliary role for hillshade data in the detecting of terrain texture direction.

Results of terrain texture periodicity and complexity analysis shows that among DEM data and its derived data, the mean variation coefficient of each texture parameter based on hillshade data is the highest, it further proves that the hillshade data is most suitable for quantitative analysis of terrain texture.

Quantification is conducted by the variance of hillshade data to texture periodicity of different terrain texture, variance eigenvalue of flat, platform, hill and mountain region gradually increases, which indicates the increase of terrain texture periodicity. Analysis is also conducted to the terrain texture complexity through angular second moment parameters computed by hillshade data, eigenvalue has clear peak value in the sample region of flat and the eigenvalue of platform decreases obviously. Eigenvalue of hills and mountain region verge to zero which shows that texture of plat has lowest complexity, followed by the lower complexity of platform and the highest complexity of hills and mountain region.

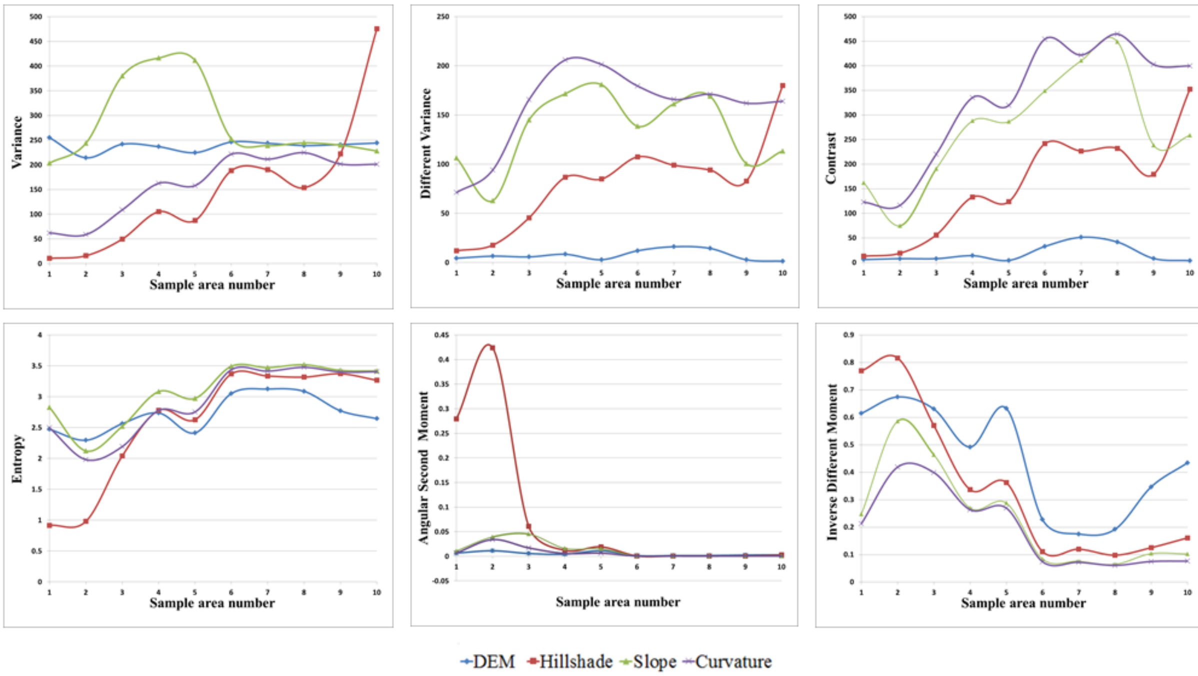


Fig.2 The calculation result of texture periodicity and texture complexity

Tab.2 Correlation coefficients between terrain texture parameters

	Variance	Different Variance	Contrast	Entropy	Angular second Moment	Inverse Different Moment	Average
DEM	0.0482	0.6899	0.9826	0.1081	0.787	0.6842	0.55
Hillshade	0.9116	0.5976	0.695	0.3734	1.8521	0.5911	0.8368
Slope	0.2873	0.2825	0.4189	0.155	1.296	0.6472	0.5145
Curvature	0.3957	0.2718	0.4	0.1945	1.4867	0.6213	0.567
Average	0.4107	0.4605	0.6242	0.2078	1.3554	0.6359	

This paper also proposes a multi-parameter integrated method which employs both comprehensive periodicity and comprehensive complexity in terrain texture quantitative analysis. This Method not only reduces replicate analyses but also makes full use of various texture parameter information, it also unifies range through normalization for the convenience of quantitative analysis. The result shows that these two parameters have significant response to the different terrain texture, which shows a great potential in landform recognition and classification.

4. Conclusions

Aiming to the shortcoming of describing the terrain characteristics on macro scale based on digital terrain analysis from DEMs, in this paper, the GLCM model a common textural analysis method is introduced into digital terrain analysis. Textural analysis methods could be used and improved to reveal the morphological and structural characteristics of landform on macro scale, which can be recognized as a new thinking for the quantification and classification of landform morphological characteristics.

5. Acknowledgments

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