Terrain similarity characterizing approach based on two-dimensional continuous wavelet

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Abstract—**characterizing and analyzing characteristics of terrain self-similarity, multi-scale and hierarchy structure have been a key point and hard problem. The traditional terrain analysis approaches based on window-shaped filters is hard to overcome the nearsighted and unsteady effects. This paper designs and realizes a new approach to analyze these self-similarity characteristics after a complete analysis of the shortness of the state of art. This paper adopts index to reveal terrain scale similarity by statistics of coefficients of continuous wavelet transformation. It takes Shannxi province as an example to calculate the scale similarity index over the province. The mechanism between the scale issues of terrain landscape and landform geomorphometry is also been analyzed by combination of index derived in the paper and experience in this area. The spatial distribution of the scale similarity index is also used to analysis the loess landscape pattern. The findings of the paper are as following: There is orderly distribution of the scale similarity over Shannxi province. The highest scale similarity appears in the northern areas with wilds and gullies, southeast areas with low hills. The local lowest similarity appears in the in-between areas of sand and loess in the northern area of the province, the Guanzhong Basin et al. The similarity in the belt of Hanzhong Basin and and Ankang falls in between these two kinds of areas. The consistency of spatial distribution of the landform morphology and the scale similarity has proved that the two dimensional continuous wavelet based methods fulfill task of characterizing scale similarity in Shannxi province. The frequency domain based approach of characterizing terrain scale similarity is a well supplication of analysis toolsets of digital terrain analysis.**

INTRODUCTION

There exists high level of self-similarity characteristic of natural and physical phenomenon. Such as stream channels, shape of watersheds, morphology in the positive and negative terrains, terrain textures and shape of contours with different elevation. Approaches of characterizing, analyzing characteristics of terrain self-similarity, multi-scale and hierarchy structure have been a key point and hard problem in both applications and researches of geosciences in the field of digital terrain analysis. Researches mainly focus on water flow in stream channels, structure of steam channels and morphology of stream channel in areas with frequency land sliders. There is few researches focus on characterizing scale similarity of terrain properties in a direct way based directly on terrain elevation data.

Frequency domain based methods are increasingly been used for scientific data analyzing, such as the wavelet based digital signal processing (DSP). These researches include three dimensional flow field data analysis (Arneodo et al, 2000; Dong Lin et al, 2004) and applications in image processing et al. Recently, the wavelet based methods are capable of characterizing features embedded in terrain morphology so that the scale issue is clearly investigated.

Generally speaking, the traditional analyzing method is hard to overcome the problem of nearsighted and unsteady effects in a single scale. Not to say finding terrain property of multi-scale issues. The state of the art methods for terrain similarity analyzing are mainly focus on terrain derivatives. Neither is it directly reflect multi-scale property of terrain, nor is it easy to characterizing similarity of multi-scales from local to global, from single to group. What's more, the shortages in acquisition of large-scale and multi-scale terrain data make it problems both in data acquisition and analysis in the aim of characterizing the multi-scale properties of terrain data. The frequency domain based methods starts from the notion of multi-scale. It is helpful of investigating the nature of terrain morphology. The results could be used as reference for terrain landform researches.

PRICIPLES OF 2D CWT

The two-dimensional continuous wavelet transformation is calculated by comprising the mother wavelet with data to be analyzed at each position. By changing the size of the mother wavelet in a continuous way, a series of wavelet coefficients at different scales at each point are collected. The formula of two-dimensional continuous wavelet transformations could be expressed as:

$$Wf(a,b,c) = CWT(a,b,c) = |a|^{-1} \int f(x)\varphi\left(\frac{x-b}{a}, \frac{y-c}{a}\right)dxdy \text{ (formula 1)}$$

Characterizing of terrain self-similarity is based on statistics of coefficients of coefficients of the 2d continuous wavelet transform.

EXPERIMENTS

SITES AND DATA SOURCES

Concerning with the representative of the method and result in this paper, test sites should meet with two conditions: 1) The test sites should cover a large area. 2) There should be a variety of landform types. What's more, the availability and representative of terrain data are also our interests. For the above concerning, we choose the whole Shannxi province as our test site covering with DEM data of 1:50,000 scale to explore the scale behavior of the loess plateau area. The source data is composited with 671 scenes of DEM whose resolution is 25m. It also meets with requirement of data accuracy whereas not too detailed for too detailed data would cause heavy computation.

ANALYSIS AND DISCUSSION

The two-dimensional continuous wavelet transformation is shown in the figure 1(Left), the brightness represents value of scale similarity. The right figure of figure 1 is a hillshade map of the whole Shannxi province, which was derived from the 671 sceneries of DEM. These two maps shows the comparison of terrain morphology and the scale similarity overall the Shannxi province.

The left one of figure 1 is the scale map of the whole Shannxi province. It is easy to see from this map that there is orderly distribution of the scale similarity over the whole province. The value of scale similarity in the northern part is relatively low compared which with the belt between Yulin and Yan'an. For this area is mainly covered by the sandy and loess mass, the repeated landform is of low similarity compared with the Yulin and Yan'an belt. For landscape is the Yulin and Yan'an belt, the highest index may mean that the landform morphology is similar in a wide range of scales, the scale ranges from 25m to 200m. The result is consistence with the existing findings in this area. The similarity concentrates in the Yan'an and Yulin belt. It means in this area, terrain landform units in every scale are of high similarity. The landform morphology in the area is undergoing very intensity interaction between the inner and outer forces and it behaves similarly in wide range of scales. The concentricity lasts to the Baoji and Tongchuan belt. In the southern area of Shannxi province, Guanzhong Basin, terrain scale similarity index is low, this is easy to see from the hillshade map of figure 1 (right). The main reason for is that the low contrast of elevation in this area, the wavelet is hard to characterizing such tiny variations. It may also owed to the accuracy of the low resolution data because there is rare accuracy data in the plat area. Another high scale similarity spot appears in the hilly area lies in the southern part of the province. It appears apparent in Shangzhou, Hanzhong and Ankang area. There is a descent sort of scale similarity of Shannxi province, namely, the loess plateau in the northern part, the Tongchuan and Baoji belt, the Shangzhou, Ankang and Hanzhong belt, the sandy and loess mixed area in the northern part, the Guanzhong Basin area. The scale similarity represents interaction intensity of the inner and outer force. The distribution of scale similarity is consistent with landform morphology reflected by the hillshade map of figure 1 (right). The consistency notifies correctness of the frequency domain based scale similarity characterizing method.

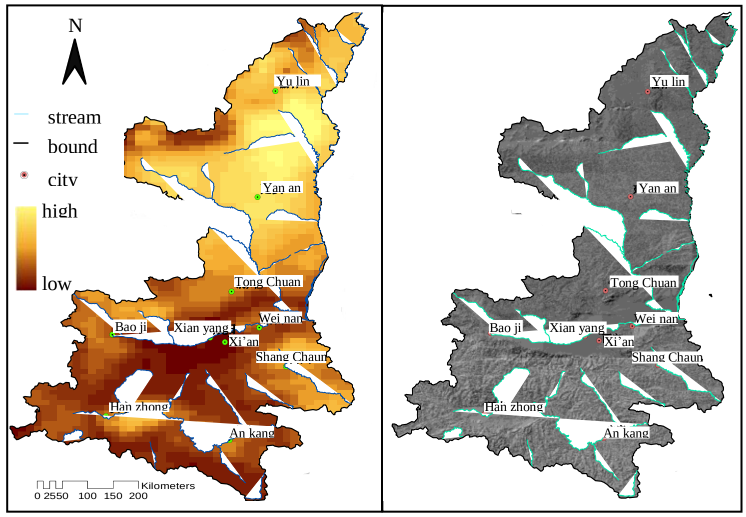

Figure 1. spatial distribution map of 2D cwt terrain self-similarity

REFERENCES

[1] Arneodo, A., Decoster, N., S.G. Roux. A wavelet-based method for multifractal image analysis. I. Methodology and test applications on isotropic and anisotropic random rough surfaces [J], Eur. Phys. J. B, 2000, 15, 567-600.

[2] Arneodo, A., F. Argoul, J. Elezgaray, G. Grasseau. Wavelet transforms analysis of fractals: application to nonequilibrium phase transitions [J], Nonlinear dynamics, 1988a.

[3] Arneodo, A., G. Grasseau & M. Holschneider Wavelet transform of multi-fractals [J]. Phys. Rev. Lett. 1988b, 61, 2281-2284.

[4] Dudgeon J.E., Gopalakrishnan R. Fractal-based modeling of 3D terrain surfaces [C], Proceedings of the IEEE Southeastcon 96. Bringing Together Education, Science and Technology, 1996, Tampa, FL, USA: 246 – 252.

[5] Herzfeld U C, Overbeck C. Analysis and Simulation of Scale-Dependent Fractal Surface with Application to Seafloor Morphology [J]. Computers & Geosciences, 1999, 25: 979-1007.

[6] Longley P A, Batty M. Fractal Measurement and Line Generalization [J], Computers & Geosciences, 1989, 15(2): 167-183.

[7] Whalley W B, Orford J D. The Use of Fractals and Pseudo fractals in the Analysis of Two-dimensional Outlines: Review and Further Exploration [J], Computers & Geosciences, 1989, 15(20):185-197.

[8] Xiangcheng Mi, Haibao Ren, Zisheng Ouyang, Wei Wei et al. The use of the Mexican Hat and the Morlet wavelets for detection of ecological patterns [J], Plant Ecology, 2005, 179: 1-19.