A Method of Automatic Topographic Recognition Based on Slope Spectrum

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Abstract—**Slope spectrum is an effective method of reflecting macro terrain feature with the quantitative micro-terrain-factor, slope, which has been attracting more and more attentions in the geomorphology research area. In this paper, a method of automatic topographic recognition based on slope spectrum was proposed. First, characters of slope spectrum derived from DEM is extracted as quantitative factors to describe terrain feature. And then, this method using BP neural network model to automatically recognize landforms from DEM data quickly and accurately, according to characters of slope spectrum. In this paper, eight sample areas from different landform types of Shaanxi Province in China are selected to test this method. As is shown in experimental results, the recognition rate is 70% on average and the best combination of terrain feature factors are found out in sample areas, which shows a great potential in landform recognition.**

INTRODUCTION

Automatic topographic recognition play an important role in the landscape classification and recognition research. Compared with the traditional artificial recognition methods, the accuracy of automatic topographic recognition is more stable without the influence of prior knowledge and work experience. The method is widely used in geomorphology indexing, digital cartography, massive data filtering and other fields. Previous studies have developed many recognition and classification method over times. Hammond [1] and Collins [2] discussed different algorithms that recognize landforms with slope and aspect. And these algorithms were implemented automatically by Dikau [3], because of the development of computer technology, Brabyn [4] and Morgan [5] reprogrammed his work latter. Some methods are proposed to recognize specific landforms. For example, Barbanente [6] developed a method for automatically recognizing ravines and cliffs. Later, the Digital Elevation Models (DEMs) as the major information source in describing morphological surfaces, is widely applied in the automatic topographic recognition. Many researchers extracted some parameters of landform from DEMs and put forward some new algorithms to extract more complex landforms [7,8,9].

Slope spectrum is an effective method which can well describe terrain feature of loess landforms in China based on the micro quantitative terrain factors, slope. Some prior research works [10, 11] show that every landform could find its corresponding slope spectrum, which is unique and is capable of reveling corresponding landform type. Based on former research, slope spectrum is investigated in automatic topographic recognition.

In this paper, back-propagation (BP) neural network is applied to automatically recognize different types of geography based on slope spectrum. The outline of the article is as follows: Section 2 introduces the study area and the method of landform recognition. In section 3 the paper provide the experimental results and analysis. Finally, Section 4 summarizes the work and concludes the paper.

MATERIALS AND METHODS

Study areas and data

Eight sample areas from different landform types of Shaanxi province in China are selected to test the new method proposed in this paper. Each study area is divided into eight basins as test sample areas. DEM data in this research is from the contours of 1:50000 topographical maps and produced by the National Geomantic Center of China with a spatial resolution of 25m. Shaanxi province 1:300 million landform zoning map is selected as a landform type reference. The study area is shown in Figure 1.

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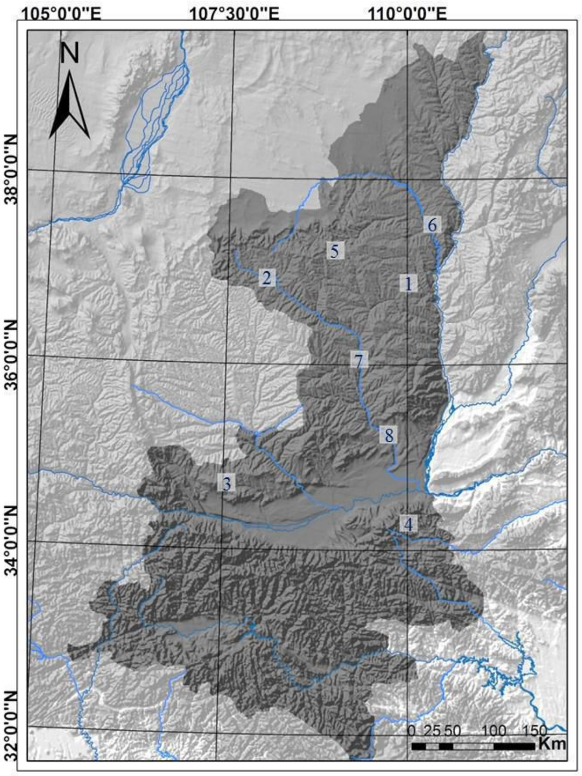

Figure 1. Study areas (1. Loess Flat-topped Ridge 2. Loess Ridge 3. Low Mountain 4. High Mountain 5. Loess Hilly-gully 6. Loess Hill-ridge 7. Loess Tableland 8. Loess Terrace)

Methods

1. Extraction of slope spectrum based on DEM

The slope spectrum is defined as a statistic graph or a mathematical model with its X-axis denoting the numerical value of the slope factors and its Y-axis is the corresponding area on the ground in a specific statistic area. The study area is in the loess plateau in China where terrain is mainly sharped by runoff erosion. And the basin is a hydrologic unit formed naturally where the exchange of energy and information is relatively independent. As a result, the graphical feature is similar inside the basin. It is advantaged to be used as a statistic area in slope spectrum for its geographical self-similarity. The method is implemented via the following steps. First, extracting basin and calculating basin area. Ten of them are selected as sample areas, each one of which is larger than thirty square meters. Second, equal interval classification of three degree is used to analysis of slope statistics in basin based on previous works.

2. Quantitation of slope spectrum

Slope spectrum parameters are acquired by quantifying slope spectrum, which are the basis of further research. The features of slope spectrum are quantified from four aspect, including information theory, statistics, morphology and landscape ecology. Not only does the quantitative characteristics describe the relations of slope combination, but also reveals the relations of space structure. As shown in Table 1, the parameters and the physical significance is redefined according to slope spectrum.

Table 1. Slope spectrum parameter

Parameter	Formula	Physical Significance
Slope Spectrum Information Entropy	$H = -\sum_{i=1}^{m} P_i \ln P_i$	Describe the degree of frequencies difference of each group of data.
Slope Spectrum Skewness	$S = \sqrt{\frac{1}{6n}} \sum_{i=1}^{n} \left(\frac{P_i - \bar{P}}{\sigma}\right)^3$	Describe the asymmetric distribution of the slope data.
Mean Slope Spectrum	$X = \frac{\sum_{i=1}^{n} X_i}{n}$	Describe the average value of slope spectrum.
Slope Spectrum Standard Deviation	$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - \mu)^2}$	Describe the dispersion degree of slope spectrum.
Termination Slope	$P_{max} = MAX(P_1, P_{2\ldots})$	Describe the maximum achievable of slope spectrum.
Patch Density	$PD = n_i * 10000 * 100/A$	Describe the fragmentation slope grading and composition.
Mean Patch Area	$AREA_{MN} = \sum_{j=1}^{n} a_{ij}/n_i$	Describe the complexity of slope classification patch shape.
Slope spectrum Aggregation Index	$AI = \left[\frac{g_{ii}}{max \rightarrow g_{ii}}\right] * 100$	Describe the reunion degree of slope spectrum in different slope classification.

3. Establishment of BP model

BP network is basically a gradient decent algorithm designed to minimize the error function in the weights space. During training of the neural network, weights are adjusted to decrease the total error. In principle, it has been proved that any continuous function can be uniformly approximated by BP network model with only one hidden layer. So a three-layer BP model is employed in our study. In this paper, the input neurons are slope spectrum parameters and the corresponding geomorphic types. The output neurons numbers are eight which depends on the classification categories.

EXPERIMENT AND ANALYSIS

In this paper, BP neural network is applied to recognize the topographic categories. Each study region contains 10 sample area in which six sample areas are selected as training sample areas to construct the recognition network. The rest four sample areas are chosen to combine with others as the test samples. This experiment includes three tests. Test 1 is consist of eight study areas, which mixed 32 sample areas, and separately identified each landform. Test 2 and Test 3 are used seven study areas, loess hilly-gully and loess hill-ridge are respectively excluded.

By using the above method to construct the automatic topographic recognition, the accuracy is shown in Table2. The accuracy means the percentage of correctly identified sample of total number of samples. The result shows that accuracy is 70% (kappa of 67.9%) in total samples, but loess hilly-gully and loess hill-ridge have poor recognition accuracy. The other two experiments are used to verify the poor recognition accuracy caused by the similarity between loess hilly-gully and loess hill-ridge, which show better result. The recognition accuracy is up to 85.7% and 92.8% respectively, and kappa coefficient is about 87%.

Table 2. Recognition accuracy

Type \ Accuracy	Test 1	Test 2	Test 3
Loess Tableland	100%	100%	100%
Loess Terrace	75%	100%	100%
Loess Flat-topped Ridge	100%	100%	100%
Loess Ridge	75%	25%	100%
Loess Hilly-gully	25%	--------	50%
Loess Hill-ridge	0%	75%	--------
Low Mountain	75%	100%	100%
High Mountain	100%	100%	100%
Total	70%	85.7%	92.8%

Recognition varies with parameter changes. The accuracy reaches the peak when using six parameters (slope spectrum information entropy, slope spectrum skewness, mean slope spectrum, slope spectrum standard deviation, termination slope、patch density) and it could be regarded as the optimal parameter combination.

CONCLUSIONS

The method of automatic topographical recognition was proposed in this paper to solve the problem of automatic identification of loess landform types. Slope spectrum and BP neural network are used in this method. It reduces the influence of subjective factors in landscape identification and proves the good correspondence between slope spectrum and loess landform. Accuracy of this experiment is 70%, but it increased to 80% when loess hilly-gully and loess hill-ridge are respectively excluded. Loess tableland and loess flat-topped ridge get the highest recognition accuracy landform in this experiment. Slope spectrum is hard to describe the difference between loess hilly-gully and loess hill-ridge under the conditions of this experiment scale. The average correction rate of recognition in test1 is lower than which in test2 and test3 because the recognition model can't distinguish loess hilly-gully and loess hill-ridge. The result shows that slope spectrum can effectively describe and recognize the characteristics of terrain surface. This method could be seen as a new trial for the quantification and recognition of landforms. Considering the complexity of actual terrain, remote sensing data and other multiple geo-data will be used to improve the landform recognition with this method in the future research.

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