Method for extraction continuous shoulder line in Loess watershed

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Abstract—**A method for automatic connection of Loess shoulder line is designed in this paper. Firstly, according to the morphological characteristics of loess hillslope, raster points on the position of shoulder-lines are detected based on high resolution DEM data. Then buffer curve of divide line sets as the initial curve. Thirdly, initial curve is forced to creep to shoulder-line points under the guidance of the hillslope flow direction matrix to make a continuous shoulder line. Experiments in the loess hilly-gully area show the continuity and precision of results meet our need and have good agreement with the real topography.**

INTRODUCTION

The Loess Plateau is famous for the typical dual structure landform, namely, the upper smooth inter-gully area and the lower cliffy gully area. This is unique landform types in the world. The loess Shoulder line, which is the dividing line of the gully area and the inter-gully area, can be found widely developed on Loess Plateau.

Due to vertical cleavage characteristics of loess, the soil materials on both sides of loess gullies will be eroded after heavy rainfall in monsoon and precipitous loess gully cliff formed. Contrasting to the upper relatively flat inter-gully area, there is obviously slope turning line between the gully area and inter-gully area[1]. This line is called shoulder line.

Existing achievements show that there are significant differences in erosion types, confluence mode, terrain slope, land use types as well as vegetation cover between the upper and lower regions of shoulder line. Meanwhile, the shoulder line plays significant role not only in controlling the loess terrain structure but also in constructing soil erosion model[2]. Therefore, basing on National GIS database and GIS spatial analysis, automatic recognition of loess shoulder line becomes a central issue research in this area.

Efficiency and accuracy are two key aspects should be concerned for extraction of shoulder line by using of digital productions of earth surface. However, extraction method based on remote sensing images can not satisfy the two aspects mentioned above simultaneously. Manually digitalizing shoulder line method based on high-resolution aerial remote sensing photographs has relatively high precision but low efficiency. Meanwhile, automatic interpretation algorithm has problem because of shadow always exists at the shoulder line area, and this interference affects the precision of extraction results greatly.

Fortunately, automatic extraction method based on high resolution Digital Elevation Model (DEM) and series of slope information data derived from it has been proved has both greater advantage in efficiency and accuracy recently. Overall, methods for extraction shoulder line based on DEMs can be summarized in three kinds. The first is to recognize shoulder line raster by using of local terrain characteristic identification method [1-4], the second is identifying inflection points on the profile of slope flow line[5], and the third is the great occlusion difference between the upper area and the lower area of shoulder line[6]. However，because of the complexity of loess terrain, discontinuous shoulder line always exists when using above-mentioned algorithm, which makes the extraction result a great constrain in modeling applications.

In this paper, an automatic loess shoulder line extraction method based on 5-meter resolution DEM data was designed. Main advantage of this method is greatly improvement in the continuity of shoulder line.

METHODOLOGY

2.1 Identification of shoulder line raster

The morphological characteristic of shoulder-lines is the slope gradient difference between the locations up and down. Fig.1 is a typical loess gully model represented by DEM combined with DOM surface layer. The dark line, which is the traverse profile line of gully, shows the structure of the hill slope

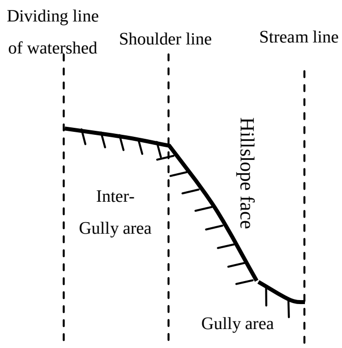

Fig.1 profile structure of hillslope in hilly-gully area

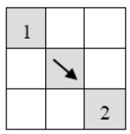

Fig.2 structure of operator

and the slope position of the shoulder-line. From which we know that the shoulder-line is the location have the biggest slope gradient variance on the direction of hillslope aspect. This is the emblematical configuration of the shoulder-line and is the theoretic foundation for automatic detection of shoulder line grid cells.

In order to identify structure of hillslope, an operator is designed for the detection. Two kind of topographic criterions are needed including the aspect matrix and slope gradient matrix which are the first derivations of the DEM data. The structure of the operator is shown in fig.2. This method is made up of following steps:

1. Detecting the hill slope direction of the central cell by aspect matrix. For example, if the aspect value of the target cell is 135°, then the cell number 1 and 2 which on the direction from northwest to southeast should be chosen for next processing.

2. Comparing slope variance (Sv) between cells detected above. Thresholds are needed in this step. Only when the Sv values exceed 20°, and the slope gradient of downstream cells should larger than the upstream cells, can the central cell be marked as the shoulder-line cells. In this example, slope of grid cell No.1 should larger than that of the cell No. 2. Then the adjacent cell would be regarded as the target cell until the whole DEM matrix was scanned over, Fig.3 shows shoulder line raster detected by this proceeding.

3. Noisy identified shoulder line cells can be removed by characteristic of cluster number less than 6.

2.2 Shoulder line raster connection under guidance of hillslope flow direction

1. Choosing Initialized connecting curve(ICC). There are two principles for choosing the location of the connecting curve in watershed. Firstly, the curve should as closed to dividing line of watershed as possible. Secondly, all of the gully area should be surrounded by the curve. Thus the boundary line buffer 2 grid to inner watershed should be the location of the ICC.

2. Hillslope flow direction matrix(HFDM), which is the guidance for creep direction of raster on ICC, can be derived from DEM data by D8 algorithm[7]. in fig.4.

3. Successively Moving rasters on the ICC by guidance of HFDM until all rasters locate on shoulder line raster identified above and gully lines. As shown in fig.5.

4. Connecting the broken shoulder line raster by order of the

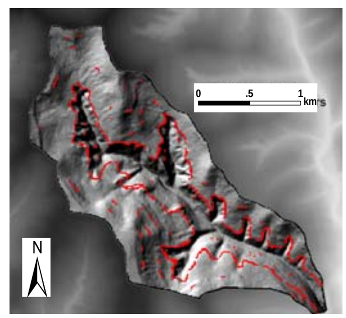

Fig.3 Shoulder line rasters

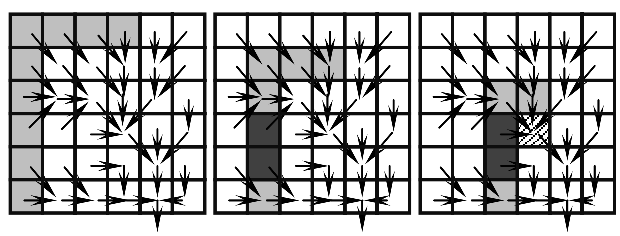

Fig.4 Locomotive processing of points on ICC

Fig. 5 Locomotive processing of ICC（white points are raster pointes on Shoulder-line, real-time location of snake curve is marked by black solid line, location of snake curve has been derived is marked by dash line）

ICC raster.

RESULT ANALYSIS

Accuracy assessment of method in this paper has been evaluated by a comparison with the manual extraction results from the 1-m resolution DOMs (Digital Ortho-image Maps).

TABLE I. PARAMETERS COMPARISON BETWEEN EXTRACTION AND STANDARD RESULTS

Location of watershed	Landform type	area (km2)	Percentage of rasters with offset distance less than 10m	Max offset distance （m）
Suide county	Hilly-gully area	3.68	91.6 %	20.3

Tables 1 give the statistic results, in which max detection offset 20.3m is achieved. This offset is equal to 4–5 grid pixels in 5-m resolution DEMs, showing a satisfied accuracy.

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REFERENCES

[1] Zhou Y, Tang G.A, Yang X, et al. 2010, “Positive and negative terrains on northern Shaanxi Loess Plateau”,Journal of Geographical Sciences. 20(1): 64-76.

[2] Lv G N, Qian Y D, 1998. “Study of automated extraction of shoulder line of valley from grid digital elevation data”. Scientia Geographica Sinica, 18(6): 567–573. (in Chinese)

[3] Zhou Y, Tang G.A, Wang C. 2010,”Automatic Segmentation of Loess Positive and Negative Terrains Based on High Resolution Grid DEMs”, SCIENTIA GEOGRAPHICA SINICA, 30（2）, 261-266. (in Chinese)

[4] Song X.D, Tang G.A, Li F.Y et al. 2013, “Extraction of loess shoulder-line based on the parallel GVF snake model in the loess hilly area of China” , Computers &Geosciences,52:11-20.

[5] Liu P J, Zhu, Q K; Wu D L et al. 2006. “Automated extraction of shoulder line of valleys based on flow paths from grid Digital Elevation Model (DEM) data”. Journal of Beijing Forestry University, 28(4): 72–76. (in Chinese)

[6] Chen Y.G, Tang G.A,and Y Zhou.2012, “The Positive and Negative Terrain of Loess Plateau Extraction Based on the Multi-azimuth DEM Shaded Relief”, SCIENTIA GEOGRAPHICA SINICA,23(1):104-109.

[7] O’Callaghan JF, Mark DM. 1984. “The extraction of drainage networks from digital elevation data”. Computer Vision, Graphics, and Image Processing 28: 323–344.