Three-Dimensional Modeling for Digital Watershed on the Loess Plateau

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Abstract：*Two methods of grid based and image based modeling were put forward respectively to represent the landform of watersheds on the Loess Plateau, China. Many kinds of spatial data such as Digital Elevation Model (DEM), Remote Sensing (RS) images, and photos are utilized to establish the digital 3-D terrains of watersheds on the Loess Plateau, which provides 3-D virtual geographic environments for supporting regional planning, conservation of water and soil, ecological environment construction. With regard to the specific landscape of terraces, a new approach to model 3-D digital terrace is designed and implemented by analyzing Grid DEM and RS image.*

Key Words：3-D modeling, watershed, Digital Elevation Model, the Loess Plateau, Terrace modeling

1.0 Introduction

The area of the Yellow River's Loess Plateau of China is more than 630 thousands sq. km, and more than 100 millions people live in this area. With arid climate and heavy desertification, this area is full of gullies, the water and soil erosion is very heavy. Thus, lots of natural disasters often happen. Modern spatial information technology such as geographic information system (GIS), remote sensing and Global Positioning System can allow us to build digital Loess Plateau for dealing with ecological problems and regional sustainable development. In this paper, 3-D modeling of digital watershed on the Loess Plateau with geographic information system (GIS) and computer visualization technique is highlighted[1,2,3].

With regard to the specific landscape of watersheds on the Loess Plateau, there are full of steep gullies, and some special objects, for instance, terraces, dams against silt flow, cave dwelling etc. Some modeling methods were used to simulate and display landscape of watersheds on the Loess Plateau.

- In grid based modeling mode, the terrain is created based on DEM data, Remote Sensing (RS) Image and other images. The terrain is made up of triangular net.
- In image based modeling mode, panorama model is constructed based on photos with Image-Based Modeling and Rendering (IBMR) technique.
- Some special method was used to simulate special artificial terrain: terrace.

2.0 Constructing 3D Terrain Models

Three-dimensional terrain is very important to research on certain area in GIS. Most of watersheds' information on the Loess Plateau can be displayed by constructing 3D terrain based on Digital Elevation Model and Remote Sensing Image. Digital Elevation Model (DEM) is digital files consisting of points of elevations, sampled systematically at equal intervals.

75	85	97	82
81	99	86	77
92	88	95	85
99	75	86	79

Fig 1. Grid DEM

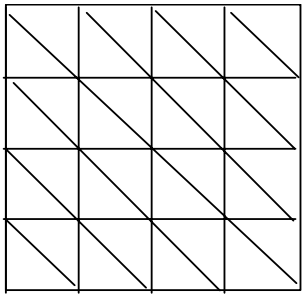

Fig 2. Trianglar network Constructing

There are three sorts of data utilized in constructing 3D terrain in this paper.

- Grid DEM data, it is from papery map of scale 1:10000, which was issued by the State Bureau of Surveying and Mapping of China. Firstly, the map is scanned into computer, and then changed to vector graph by GIS software, such as ArcGis or MapInfo, most vector graph is digital contour line, and then GIS software can produce Grid Dem automatically (see Figure 1). There is another popular format of Dem, namely Triangular Irregular Net (TIN) can be created. Grid is selected in constructing terrain of watershed on the Loess Plateau for the following reasons[4,5,6,7].

1. Because of equal intervals, the grid data can be easily constructed in the triangle net (see Figure 2).
2. Random column and row of Grid can be read easily, so large scale terrain can be divided into some small pieces. Using the small pieces of grid file, not only the speed of constructing can be accelerated, but also the requirement of computer hardware can be easily satisfied.
3. The structure of all texture Data in this paper is in regular grid, so grid based terrain can be easily texture mapped.

Comparing with Triangular Irregular Net, gird data have too many redundant triangles when the terrain being constructed, thus, data's quantity of the same area is larger than TIN.

The points of Grid are linked to each other when constructing terrain (see Figure 2). After Normal of each triangle being calculated and the light rendering, the 3D terrain is constructed (see Figure 3).

Fig 3. Terrain of RS Image overlaid

Fig 4. Terrain of contour map overlaid

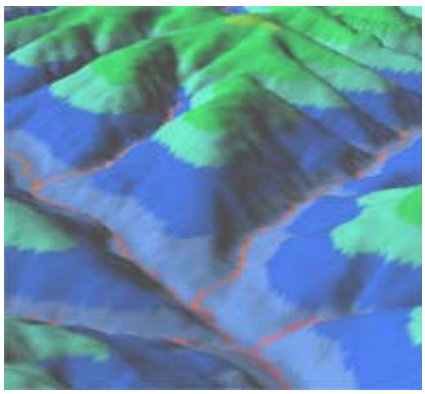

Fig 5. Terrain of gully lines overlaid

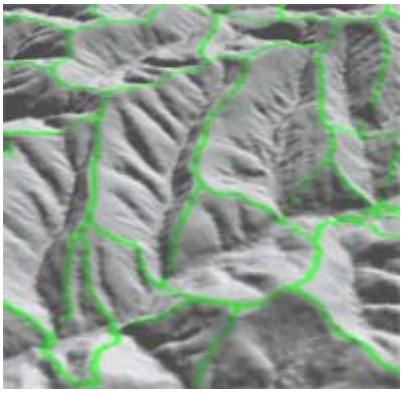

Fig 6. Terrain of sub-watershed overlaid

Texture mapping technique is a method of adding reality to a computer-generated graph. In this paper, texture mapping can also be used to analyze an area spatially. The source data of texture mapping have two types: Remote Sensing Images and other images of spatial statistics and spatial analysis, which interpreted from Remote Sensing (RS) images or calculated from Data mining of DEM. The RS images in this paper are Spot 5 RS images and their resolution is 2.5m. Spatial data images include map of gully, map of classified gully, map of classified gradients, map of sub-watershed partition, and map of land utilization etc (see Fig3, Fig4, Fig5, and Fig6).

All the images must be stretched in order to its columns and rows being equal or multiple to that of Grid DEM. Otherwise, the texture mapping can not be fulfilled.

RS images have more information of the earth surface, and other images of spatial data play an important role in region layout, conservation of water and soil, ecology construction and gully project of watershed on the Loess Plateau.

3.0 Panorama model based on IBMR technique

The terrain is constructed base on Grid, RS images and so on. All these data are horizontal information essentially, so the 3D terrain base on Gird is only of the horizontal characteristics of the Loess Plateau. But there are so many gullies in the area, the detail information of the side gully or cliff can not be contained in horizontal information data. For example, the cameras on satellite or plane take RS

images in the direction of perpendicular to the earth surface, so most information in a RS image is horizontal information, and most vertical information between two points in the vertical direction surveyed by satellite is lost (see Figure 7).

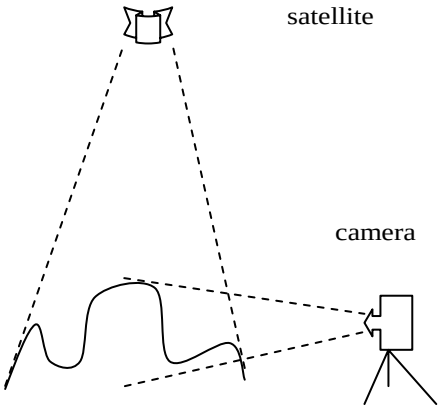

Fig 7. Differences between data of two modelings

Furthermore, most of dwellers in the Loess Plateau live in the caves dwelling, it is a hole excavated on the sides of hill, and can not be seen in RS images. In order to represent the vertical information of the terrain, the panorama model based on IBMR is built.

Image-based modeling and rendering differs from traditional graphic techniques in deriving both the geometry and appearance of the scene from real photographs. The techniques often allow shorter modeling times, faster rendering speeds, and unprecedented levels of photorealism.

The panorama model is created with real photos took by Canon 20D camera, the fisheye lens make the photo a hemisphere and the camera angle is 184 degrees. On a fixed tripod, take two photos on reverse directions. The two photos was put together with the Scene Master software, which was issued by Jietusoft Company of Shanghai, and the simple panorama model of the Loess Plateau is built (see Figure 8,9).

Fig 8. Panorama modeling based on IBMR

Fig 9. Panorama modeling

The data of panorama model, namely the photographs, was shot in nearly perpendicular to the side of gully and the cave dwelling and so on, so the vertical information of the modeling area is represented well than the 3D terrain. For high resolution of the photos, most of the detail information is displayed too. So the panorama model base on IBMR is a good supplementary of the grid based 3D terrain.

4.0 Terrace Modeling

The ancient art of terracing has been a mainstay of subsistence agriculture in the region. Terrace is an effective architecture for preventing soil erosion and improvement of ecological environment. There are many types of Terraces in watershed on the Loess Plateau; the width of some is less than 7 m, so it is difficult to represent the geometry characteristics of the special artificial terrain, with the foregoing terrain modeling. In order to get better visual impression, a new modeling method is put forward[8-12].

The source data of modeling is papery relief map of 1:10000 scale and SPOT 5 Remote Sensing Images, which resolution is 2.5 meter. The area is Jiuyuangou watershed in Suide county, Yulin City, ShanXi province of China. The method of making relief map into Grid DEM data is same as the foregoing. Had been geometry adjusted, the RS Image was interpreted by Erdas software to distinguish the outline and position of each layer. Then the outline of each layer was lined out in ArcView, which is a subsystem of the most popular GIS software, ArcGIS (Figure 10).

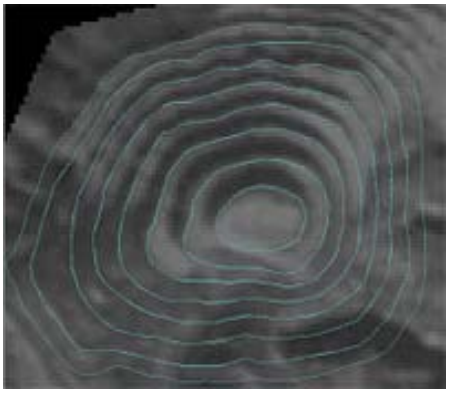

Fig 10. Outlines of terraces

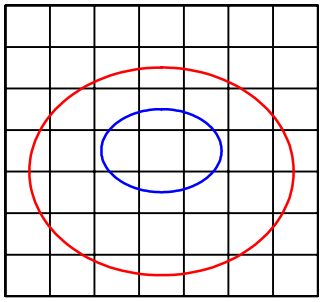

Fig 11. Overlay of Grid DEM and outlines of terraces

Then the outline is overlaid on the Grid (see figure 11). Every lattice of Grid is merged into the corresponding group by judging the intersection of the lines and lattices. For example, all the lattices that intersect with red line are classified to the same group. Then the mean value of each group is calculated and replaces the origin elevation value of each lattice in the group. All the lattice of intersection is utilized to constructing terrain, and other points are discarded (see Figure12,13,14).

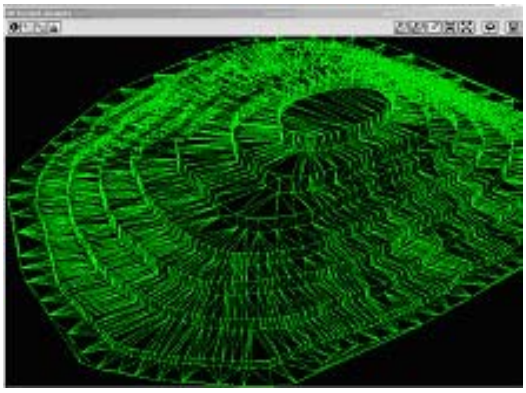

Fig 12. Triangular network of terrace

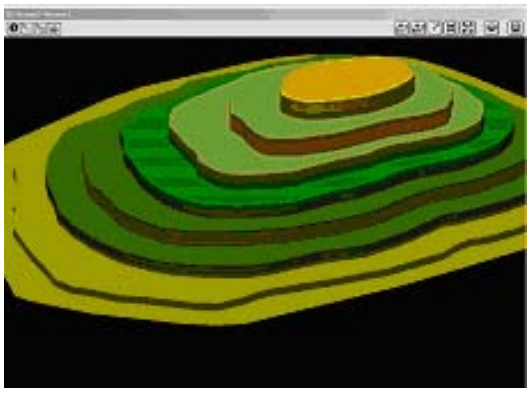

Fig 13. Modeling of terrace

Fig 14. Real photo of terrace

The terrain of terrace constructed by this method has better visual effect than traditional modeling. The most important error is from the interpretation of RS images, so investigation on the spot is recommended to confirm the outlines of terraces.

5.0 Conclusion

As a specific landform, modeling of the Loess Plateau is still a difficult issue. In view of the 3-D construction of digital watersheds and digital Loess Plateau, there exist many approaches to different spatial scales and details. In this paper, the grid based and image based modeling methods for handling watersheds on the Loess Plateau, and the characteristics of both methods are discussed. The new modeling method based on overlay analysis for Grid DEM and RS images is presented for the special artificial landform-terrace.

6.0 Acknowledgement

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7.0 References

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