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A Kind of New Surface Modeling Method Based on DEM Data

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Abstract

Surface elevation changes greatly in the river erosion area. Due to the limitation of the acquisition equipment and cost, the traditional seismic acquisition data has sparse physical points both horizontally and longitudinally, the density of surface measurement data is not enough to survey the surface structure in detail. With the development of science and technology, and the application of satellite technology, the DEM elevation data obtained from the geographic information system (GIS) are becoming more and more accurate. In this paper, a precise modeling is performed on the surface based on the geographic information from the river erosion area and combined with the results of the surface survey control points, a good effect is achieved.

Key words: River erosion area; Geographic information; Similarity coefficient; Kriging interpolation; Surface modeling; High and low frequency statics

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INTRODUCTION

Geographic Information refers to the information related to spatial geographic distribution. It expresses the inherent quantity, quality and distributional characteristics of land surface object and environment, which contain electronic map, satellite navigation and remote-sensing image[1]. At present, the DEM (Digital Elevation Model) data grid in the geographic information system (GIS) has reached the resolution of 30 m, which has provided the plane coordinates (X, Y) for the specifications network and the data set of its elevation (Z).

River erosion landform is a kind of landform formed by massif with the surface elevation changes intensively under the influence of rain and river erosion (Figure 1). In the course of seismic data acquisition, the surface elevation obtained through field measurement has been the basis for surface modeling and statics calculation. There is certain line spacing in 2D and 3D seismic survey transversely. In the actual calculation process, the elevation data in the blank area are calculated through the interpolation, which has limited the accuracy.

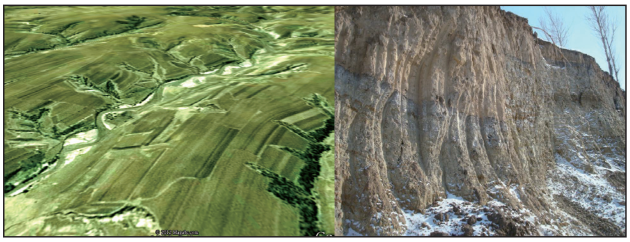


Figure 1
Ground Surface in the River Erosion Area

1. THEORETICAL ANALYSIS

1.1 Similarity Coefficient

Similarity coefficient is an indicator to express the similarity degree between two classification units as the objects. In the modeling process of surface survey control points, similarity coefficient is an important parameter (Figure 2). Selection of similarity coefficient: the selection range is from -1 to 1. “1” means that the forms of the two layer interfaces are completely similar; “0” means that the forms of the two layer interfaces are completely dissimilar; "0.5" means that the forms of the two layer interfaces have 50% similarity.

$$h_G = z_{AB} + (E_G - E_C) \times (1 - k) \qquad (1)$$

Where, h_G means the LVL thickness (m) of Point G; Z_{AB} means the thickness of Point G obtained by linear interpolation between the thicknesses (m) of Point A and B; E_G means the altitude above sea level (m) of Point G on the surface; E_C means the altitude above seal level (m) of Point C; and K means the similarity coefficient.

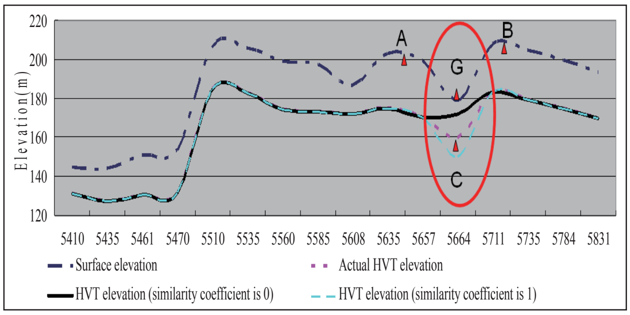


Figure 2
Comparison Between Different Similarity Coefficients

1.2 Kriging Interpolation

In the field operation, there is a certain distance between two survey lines. While extracting the surface elevation, the Kriging interpolation method is adopted[2], which is also called the space local interpolation method. It is a kind of method to make unbiased optimal estimation to regionalized variables in a limited area based on the variation function theory and structure analysis.

$$Z(x_0) = \sum_{i=1}^{n} \omega Z(x_i) \qquad (2)$$

Where, $Z(x_0)$ means the value of the unknown sample point; $Z(x_i)$ means the value of the known sample point around the unknown sample point; n means the number of the known sample points; ω means the weighing of the ith known sample point to the unknown sample point.

When to interpolate with the Kriging interpolation formula, the more the known sample point number within a certain space range, the more accurate the value of the unknown sample point will be.

1.3 Statics Calculation

To establish the surface model according to the surface survey control points, the similarity coefficient is involved in the operation as an important parameter. Using the similarity coefficient formula (1), you can see that the surface elevation influences the modeling accuracy. Under the condition that the number of the surface survey control points is fixed, the higher the density of the surface elevation sample points that are involved into the calculation, the more accuracy of the surface model calculated with Kriging interpolation will be.

The static correction error formula is derived from the surface survey control point based statics calculation formula[3]:

$$T = \left(\frac{h_2}{v_2} - \frac{h_1}{v_1} - \frac{h_1 - h_2}{V_s} \right) \times 1000 \qquad (3)$$

Where, T means the source statics or the receive statics(ms); h_i means the LVL thickness (m) for the i^{th} point; V_i means the surface layer velocity for the i^{th} point; and V_s means the datum correction velocity (m/s).

Different LVL thickness produced by different high velocity top (HVT) can cause the variation of statics. Given the known area replacement velocity, the variation of the surface velocity has a direct impact on the variation trend of statics (Figure 3).

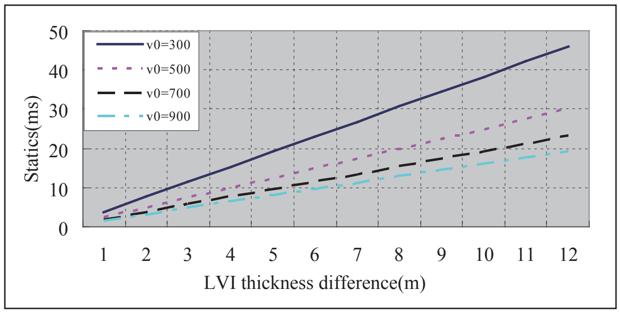


Figure 3
Dependence of Static Correction Errors

2. APPLICATION

2.1 Actual Density Analysis

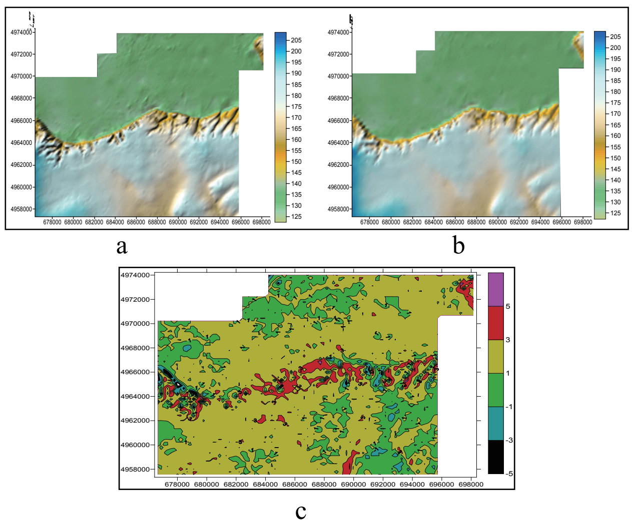


Figure 4
Actual Surface Elevation Data Obtained Through Different Methods. a: Actual Field Receive Line Space is 160 m; b: Actual Field Receive Line Space is 320 m; c: The HVT Difference Established Through the Above Two Methods

A 3D survey area in JL is selected. Receive interval is 40m, receive line interval is 160m and 16 lines are used for receiving. The actual field survey elevation data is vacuated to enlarge the receive line spacing; and then observe the modeling accuracy which are influenced by different sampling point density of actual data (Figure 4).

As shown in Figures 4a and 4b, the accuracy of the vacuated surface elevation data is lower than that of the actual surface elevation. Contrasting the surface models created under the two types of above conditions, the HVT elevation difference is bigger, showing that the accuracy of the extracted surface model becomes smaller with the decreasing of the density of the surface sampling points.

2.2 Error Analysis

The 30m-resolution DEM data are used to establish a surface model. Due to the even distribution of points in both horizontal and longitudinal directions (Figure 5), the density of the survey point obtained is even higher.

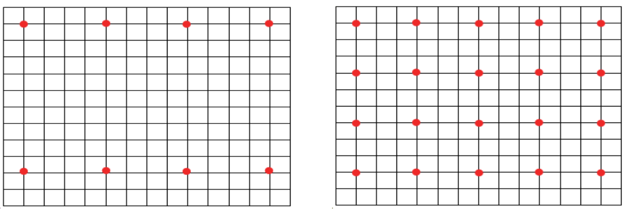


Figure 5
The Surface Elevation Data Density Obtained Through Different Methods. Left: Actual Field Survey; Right: DEM Elevation Data

Through the comparison between the field actual measurement elevation data before and after vacuation with the geographic information elevation data, it can be observed from the 3 curves in Figure 6 that with the increase of point density, the variation of DEM data surface elevation is depicted more finely. The DEM elevation data coincides with the surface fluctuation trend of the actual field measurement elevation data only with a certain elevation error.

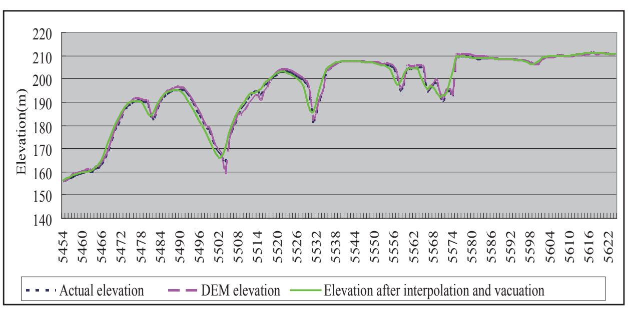
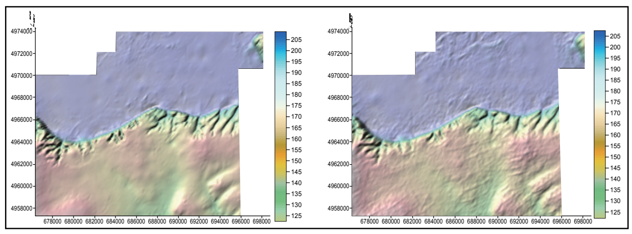


Figure 6
Comparison of the Surface Elevation Data Obtained Along a Line Through Different Methods

In order to analyze the influence of such error to modeling accuracy, the geographic information elevation data is vacuated. The sample points obtained are same as the sampling points received by 16 actual lines. The difference between the surface models established in two ways is compared.

With same modeling parameters, the difference between the interpolated blank area and the model established with DEM data is relatively large due to the small density of actual data sampling points. But through the extraction non blank area DEM elevation data and actual data contrast, elevation value is the same; however, comparing the DEM elevation data after extraction of non-blank area with the actual data, the elevation values are same.

Based on the above analysis, when to use the geographic elevation data in the whole area to establish the surface model, the more of the known sampling points without a fixed space area, the more accurate can a surface structure be obtained (Figure 7).



a b

Figure 7
The HVT Elevation Spatial Model Established with Different Surface Elevation Data. a: HVT Established with Actual Field Survey; b: HVT Established with DEM Elevation Data

2.3 Application of DEM Data

Through the above analysis, the DEM elevation data is able to build surface model and therefore the surface structure obtained can be applied in the actual data.

The DEM elevation data is used to establish the surface model. An appropriate similarity coefficient for the river erosion area is selected to calculate the LVL thickness in the work area and the statics.

The river erosion area is compared with different elevation static correction methods. After applying the geographic information elevation data to calculate the elevation statics and the field measured elevation to calculate the elevation statics, two stack sections are the same in shape (Figure 8) and can get the interlayer information.

In order to analyze the causes, their respective elevation statics are compared. The surface statics is calculated according to the statics error formula. The statics difference value range is –20 ms to +20 ms (Figure 9).

The statics are broken down into low and high frequency contents[4]. Compare the influences of high and low frequency statics to the stack section (Figure 10). The low frequency statics calculated with the geographic information elevation data is similar to the low frequency statics calculated with actual elevation and their overall forms are completely consistent, but only local high frequency statics have a different value.

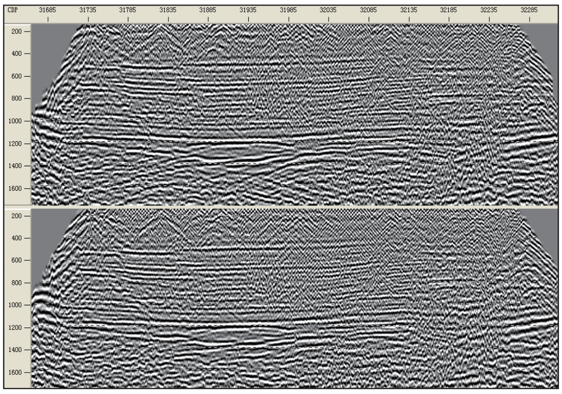


Figure 8
Comparison of the Stack Sections Using Different Elevation Statics. Upper: Field Survey Statics; Lower: DEM Statics

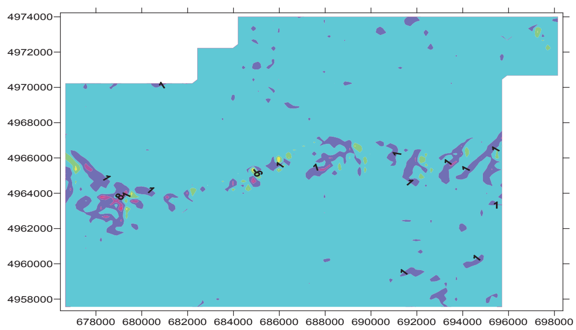


Figure 9
Elevation Statics Difference in Rive Erosion Area

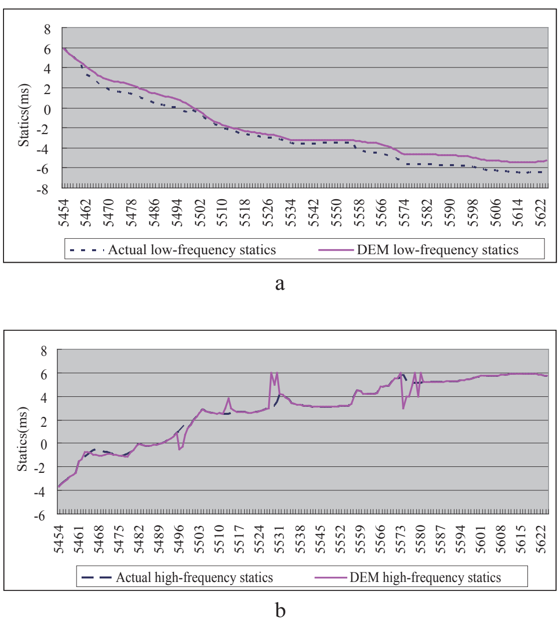


Figure 10
The Statics Established with Different Surface Elevation Data Along a Line. a: Low-Frequency Statics Comparison; b: High-Frequency Statics Comparison

Therefore, using terrain to control low-frequency statics and using DEM data to depict high frequency statics are a kind of method which is able to obtain an ideal stack section, indicating that the surface model established with DEM data is appropriate.

It is not an objective that we are seeking for to perform stack processing with the statics obtained with DEN elevation data and the final section in the actual data calculation; however, through the stack section contrast, the accurate surface model established based on the geographic information elevation data can be used in surface survey and static correction processing.

The application of the above information is mainly aimed at the area with complex elevation changes; as for the area with flat surface elevation changes, this method is also applicable for modeling; nevertheless, for the area with special surface lithology, for instance the desert area shown in Figure 11, due to its weathering and sand dune migration, the application of this method has certain limitations.

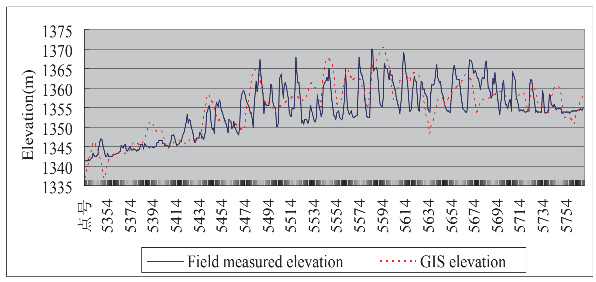


Figure 11
Comparison of Elevation Data in Desert Area

CONCLUSIONS

(1) Modeling with GIS, the density of surface sampling points is high and the accuracy of surface modeling in river erosion area can improved.

(2) The surface model establish with GIS is an important method that details the surface structure at the initial stage; at the same time, it can assist to design the excitation depth of hole.

(3) Using the elevation statics calculated with GIS, the stack effect and the elevation statics stack effect calculated with field elevation are similar.

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