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Production of Digital Elevation Models (DEMs) Using Some of Interpolation Methods Based on Surfer Program

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Abstract

Topographic maps are a popular sort of map used in many geomatics applications. The most commonly used digital format for storing and analyzing height data is the Digital Elevation Model (DEM), which represents the earth's topography and may be produced using various data sources. This paper aims to produce digital elevation models (DEMs) using several interpolation methods within a Surfer software package. Numerous generic interpolation techniques were studied, such as inverse distance to power, triangulation with linear interpolation, the nearest neighbor, and kriging. The Surfer package utilizes the grid and various interpolation techniques to generate various digital elevation models, allowing researchers to explore the range of interpolation techniques based on the quantity and distribution of points. Many grid options allow the user to produce the best digital elevation model. The results demonstrated that the DEMs' accuracy was within computed limits for variance, Root Mean Square Error, and coefficient of determination (R^2). Kriging provides accurate statistical data and is adaptable. It has a minimum RMSE (0.0053), and the (R^2) was getting close to one.

Keywords: Surfer software, DEMs, Interpolation techniques, RMSE, and coefficient of determination

إنتاج نماذج الارتفاعات الرقمية باستخدام بعض طرق الاستيفاء المعتمدة على برنامج سيرفر

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الخلاصة

تمثل الخرائط الطبوغرافية نوعًا رئيسيًا من الخرائط المستخدمة في العديد من تطبيقات الجيوماتكس. التنسيق الرقمي الأكثر استخدامًا لتخزين وتحليل بيانات الارتفاع هو نموذج الارتفاع الرقمي لتمثيل تضاريس

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الأرض التي يمكن إنتاجها باستخدام مصادر بيانات مختلفة. تهدف هذه الورقة إلى إنتاج نماذج الارتفاع الرقمية باستخدام عدة طرق استيفاء ضمن حزمة برنامج سيرفر. تمت دراسة العديد من تقنيات الاستيفاء العامة، باستخدام المسافة العكسية للقوة، والتثليث مع الاستيفاء الخطي، وأقرب جار، وKriging. تستخدم حزمة سيرفر الشبكة وتقنيات الاستيفاء المختلفة لإنشاء نماذج الارتفاع الرقمية المختلفة، مما يسمح للباحثين باستكشاف مجموعة من تقنيات الاستيفاء بناءً على كمية النقاط وتوزيعها. تتوفر العديد من خيارات الشبكة، مما يسمح للمستخدم بإنتاج أفضل نموذج رقمي للارتفاع. أظهرت النتائج أن دقة نماذج الارتفاع الرقمي كانت ضمن الحدود المحسوبة للتباين وجذر متوسط مربع الخطأ RMSE ومعامل التحديد. يوفر Kriging بيانات إحصائية دقيقة وقابلة للتكيف. لديها الحد الأدنى من RMSE (0.0053)، وكان معامل التحديد يقترب من واحد.

1. Introduction

Digital elevation models (DEMs) are among the most important sources of surface elevations for applications that require the representation of features and terrain [1-4]. Digital elevation model values are obtained from various sources using modern techniques such as ground measurements, Global Navigation Satellite Systems (GNSS) data, aerial photographs, Global Digital Elevation Models (GDEMs), and Remote Sensing Techniques [5]. The surfer grid can create various maps, including contour, vectoring, color relief (image), shaded relief, 3-D surface, and three-dimensional wireframe maps [6]. On the other hand, GIS programs allow for the management, processing, and analysis of DEMs to produce many different types of mapping topography [5], the analysis of fluvial landscapes in mountainous regions, the building of topographical maps, and geoid models [7]. Although Surfer internally calculates the algorithms, selecting the appropriate gridding technique for the data can be challenging. Surfer offers a variety of gridding systems, each with its own set of gridding parameters [6].

The current study used a Surfer program to create digital elevation maps employing four alternative interpolation methods: Inverse Distance to Power, Nearest Neighbor, Triangulation with Linear Interpolation, and kriging. Three statistical results have been generated from the examination of four distinct gridding.

2. Materials and Methods

2.1 The Study Area

Approximately 8600 locations are regularly dispersed in Fallujah City (west of Iraq) were observed; it is located between the Latitude from (3693136.77 to 3692795.452) N and Longitude from (385961.612 to 384749.613) E according to UTM projection. They were acquired using the Differential Global Positioning System (DGPS) based on an SP80 GNSS receiver. Figure -1 displays the spatial distribution of Ground Control Points (GCPs) within the study area in Two Dimensional (2D) on a post map.

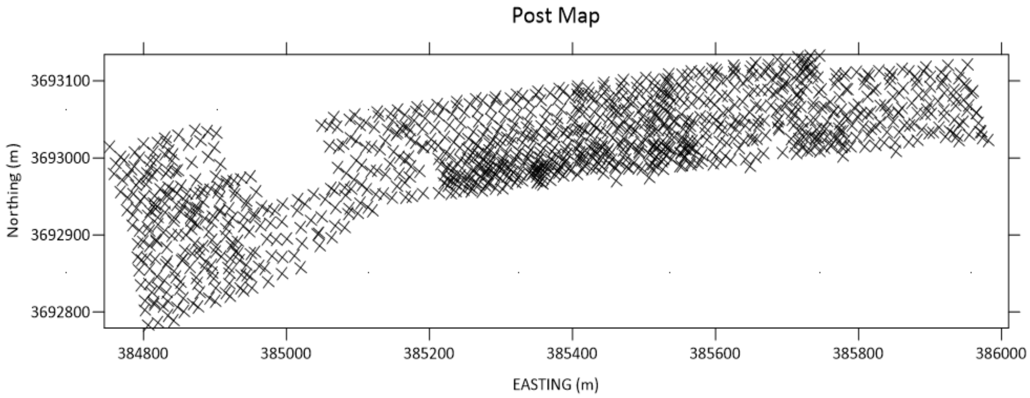


Figure 1: Distribution of GCPs in the study area as post-map.

2.2 Methodology and steps of DEM map production

DEM maps in the surfer program were created from gridded data. SURFER is a 3D surface mapping program that transforms Excel file data into contours and a grid-based map using the interpolation method. The grid method parameters affect the interpolation procedures. The default gridding approach used when creating a grid file is typically sufficient to produce an acceptable map; four gridding methods were used in this study (Kriging, Inverse Distance to Power, Nearest Neighbor, and Triangulation with Linear Interpolation)

- **Kriging**

The Kriging method creates visually pleasing maps from irregularly arranged data [6]. Kriging can be described mathematically as in Eq. (1).

$$z = \sum_{i=1}^{n} wi * zi \tag{1}$$

Where:
n: the number of surrounding points
zi: the height of the adjacent point
z: the predicted height
wi: the weight of each point

- **Inverse Distance to Power**

The Inverse Distance to a Power: During interpolation, data are weighted so that the distance from the grid node decreases according to the relative significance of each point [6]. Equation (2) describes the mathematical form of the Inverse Distance to a Power method.

$$z = \frac{\sum_{i=1}^{n} zi * wi}{\sum_{i=1}^{n} wi} \tag{2}$$

Where:
zi: the height of the adjacent point
z: the predicted height
wi: the weight of each point

- **Nearest Neighbor**

The Nearest Neighbor method assigns the value of the nearest point to each grid node [6]. The Nearest Neighbor formula can be expressed as in Eq. (3):

$$z = \frac{\sum_{i=1}^{n} zi}{n} \tag{3}$$

- **Triangulation with Linear Interpolation**

In the Triangulation with Linear Interpolation method, the algorithm creates triangles by drawing lines between data points. The initial points are joined so no edges cross into another triangle [6].

The Root Mean Square Error (R.M.S.E)

The Root Mean Square Error (R.M.S.E), Correlation of determination value (R^2), and Variance were utilized to evaluate the accuracy of digital elevation models produced by the Surfer Package, Table 1. The Root Mean Square Error (R.M.S.E) was used as a statistical accuracy estimation factor, as explained in Eq. (4) and Eq. (50) [8].

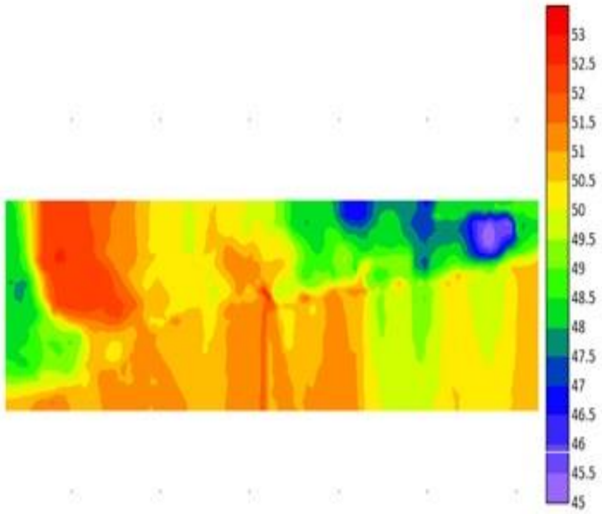
$$\text{RMSE} = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(Difference)_2} \qquad (4)$$

Difference= predicted height- observed height (5)

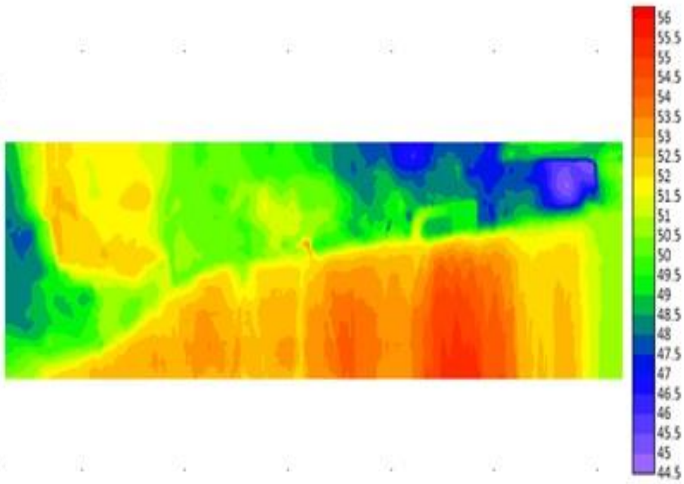
Where n is the number of points.

3. Results and Discussion

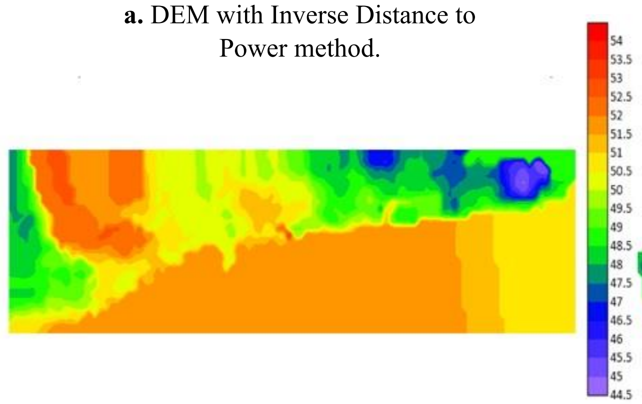
This work used four interpolation methods to generate Digital Elevation Model maps based on the Surfer package, Figure -2.



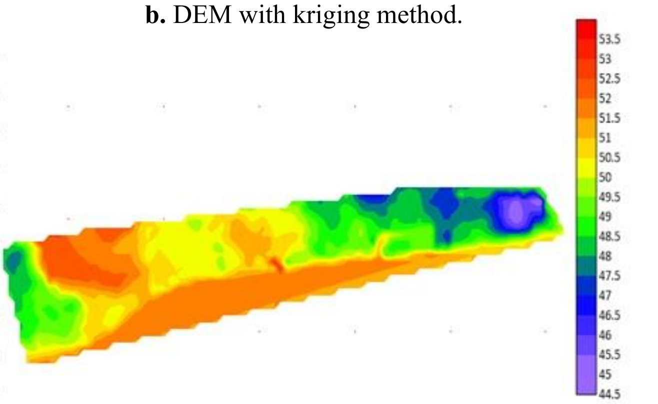
a. DEM with Inverse Distance to Power method.



b. DEM with kriging method.



c. DEM using nearest-neighbour method.



d. DEM using triangulation using with Interpolation method.

Figure 2: DEM using different methods (Prepared by Author).

After obtaining the statistical values of the four methods recorded in Table 1, Figure -3 shows the relationship between Root Mean Square Error values and the four gridding methods used. In the same way, the coefficient of determination value and variance are shown in Figures 4 and 5. These Figures concluded that Kriging is the more suitable gridding method for the Digital Elevation Model because of its statistical values. The minimum RMSE was 0.0053 for kriging, and the maximum RMSE was 0.2553 for Triangulation with linear Interpolation, Figure -3. In kriging, the Variance also reached 0.3765, and the Coefficient of determination (R^2) was close to one, as shown in Figures 4 and 5. The Inverse Distance to Power method result was that RMSE was 0.3155 and R^2 was 0.2041. The nearest-neighbor method is considered the best after the kriging method because of the coefficient of determination of the R^2 value, which is also close to one, while the error rate was 0.0166.

Table 1: Statistical results and comparison between Surfer Gridding methods

No.	Gridding method	Elapsed time for gridding	(R^2)	root-mean-square error (meter)	Variance (meter)	Grid Size
1	Inverse Distance to Power	0.22 seconds	0.3155	0.2041	1.6337	70 rows x 300 columns
2	Kriging	2.04 seconds	0.9981	0.0053	0.3765	70 rows x 300 columns
3	Nearest-Neighbor	0.04 seconds	0.8781	0.0166	0.9006	70 rows x 300 columns
4	Triangulation using linear Interpolation	0.03 seconds	0.3781	0.2553	1.5705	70 rows x 300 columns

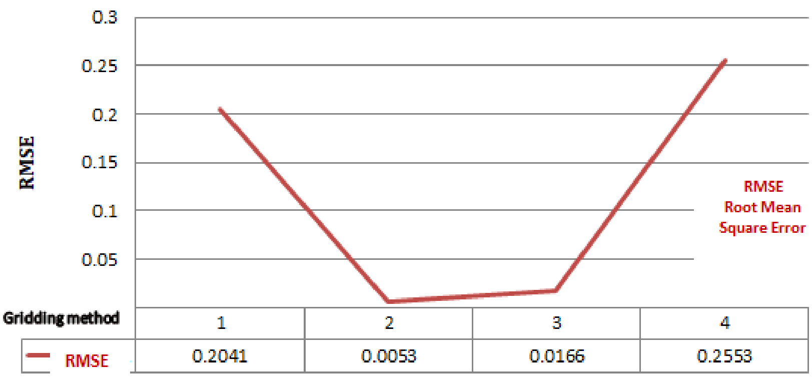


Figure 3: Gridding method VS RMSE

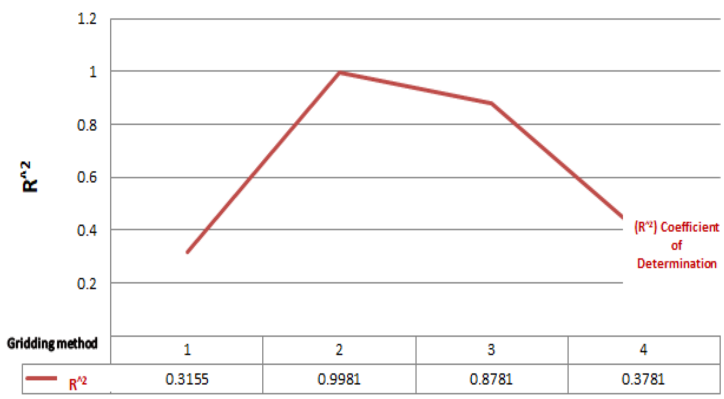


Figure 4: Gridding method VS R^2

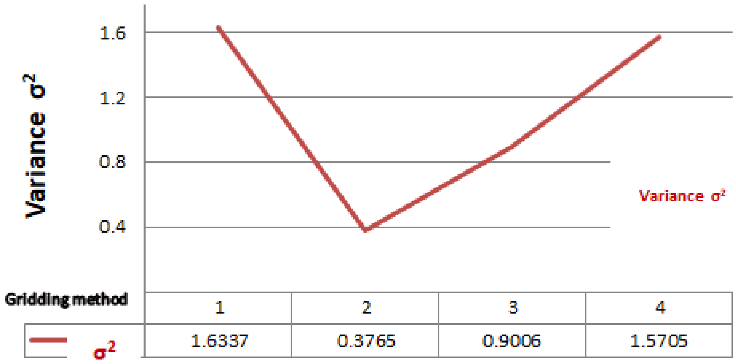


Figure 5: Gridding Method VS Variance

4. Conclusions

After conducting this study, it can be concluded that there was no perfect gridding approach for every sort of data. Three statistical results were obtained after testing four different gridding techniques. Kriging was an excellent choice for a digital elevation model since it was a more acceptable gridding method and because statistical values are relevant. The minimum RMSE was 0.0053 for kriging and the maximum RMSE was 0.2553 for Triangulation with linear Interpolation. In kriging, the (R^2) was getting close to one. Kriging provides accurate statistical data and is adaptable. Regarding task speed, it is thought that the (triangulation using the Linear Interpolation method) is quick and gives a reliable representation of data, but (Kriging) creates grids more slowly than the other methods.

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