ANALYSIS OF THE PROBLEMS OF INTERPOLATION IN GIS MEDIUM

George Valev, Penka Kastreva

Abstract

The spatial interpolation is a widely spread operation in GIS. In a previous paper [6] of the authors it has made a brief overview of the contemporary state of the technology for modeling a topographic surface by means of interpolation of intermediate values. This paper stresses on the practical application of the interpolation methods. The paper has discussed in detail four methods of grid interpolation: Inverse Distance Weighted (IDW), Natural Neighbor, Kriging and Spline. It describes in more details the third method and the models, which are used. In this paper an analysis of the problems of the interpolation in GIS medium is done. The paper discusses the factors, which define the appropriate method for interpolation, the barriers in interpolation as well as the practical application and comparative analysis of the methods. It discusses the linear and non-linear interpolation. Some numerical examples are applied.

Key words: *interpolation, Kriging, TIN, IDW*

1. INTRODUCTION

In the previous paper [6] several interpolation methods were discussed. It is theoretically and practically proven that some are more precise than others.
Linear interpolation. This method is standard in the production of topographic maps. It is applied for territories with known heights of the points and the places where the slopes change. This allows precise linear interpolation among the heights. The contour lines are obtained by means of interpolation among the nearest neighbouring points.
GRID interpolation. The simplest way of creating a grid surface is the linear GRID interpolation. The contour lines from fig.6 to fig. 11 are resulting from GRID interpolation of the apexes of the obtained grid network with size 5x5 m.
IDW. Another used interpolation method is IDW (inverse distance method). In this case the values of the apexes of the grid network are averaged by the values of all points that occur in a chosen radius around a grid apex. The weights are inversely proportional to the distances so that the more distant ones have less influence on the value of the height.
Kriging is an interpolation method where the value of each apex from the grid network is a sum of the values of points with a different zone of influence similar to IDW but with a more complex system for reading the weights. In GIS several Kriging parameters are introduced (Davis, 1986) in order to get results. These parameters are: *range* – the distance where the values of the points become insignificantly average; *drift* is the general slope of the surface, which can be presented with a zero or by means of a more complex mathematical equation – linear and square. The choice of the slope as square allows the modeling of the surface to be more complex. Higher values than the zero value lead to modeling of smooth surfaces. Kriging has two basic forms. Ordinary and Universal Kriging are often used in GIS. The main form is Universal Kriging. It is used when the surface is calculated by irregularly distributed points. The results of the Kriging interpolation are function of the choice of the introduced map parameters. The decrease of the size of the grid network increases the complexity of the surface of the plane as multiple small closed contours located on larger structural forms.

2. THE CHOSE OF A METHOD

When whatever of the methods is applied several factors should be taken into consideration: choice of neighbouring points; choice of TIN or GRID network; the number of the used control points; the location of the used control points; the problem with the saddle points; the territory containing the point data; defining the appropriate interpolation method; the barriers of interpolation.
The drawing of the contour lines among points with measured heights requires first to decide which points of the set of data to be used. This decision is not easy neither simple. **The choice of neighbouring points** among which the isolines (contour lines) should be drawn has influence on the final shape of the surface.
The next decision is whether drawing the contour lines should be based on **TIN** or **GRID** network. The most direct way is to connect neighboring points so that an irregular network of triangles is obtained. For a long time the TIN method has been a preferred approach for manual drawing of contour lines and later became popular also in the computer technologies. The initial advantage of the method is that it is very quick to accomplish. The surface with contour lines precisely corresponds to the data and can be easily modeled manually. Another valuable property is that the TIN

network drawn in the three-dimensional space can show the approximate shape of the surface. As it has been mentioned the TIN network includes finding the closest neighbouring points that form the apexes of the network.
The grid network includes laying of a coordinate network on the data and interpolation in order to identify the values in the apexes (the points of intersection) of the grid network. We have discussed many different interpolation methods that are used in the modeling of grid surfaces. Most include some form of average weights of points with definite distances near every grid junction.
Usually we can say for sure that with more model points the interpolation is more precise. Despite that, however, there is a limit where the number of the used points for every surface is considered to be optimal. For instance a decrease of points in a flat terrain is necessary since with a greater **number of points** the quality is not considerably improved, instead, quite often the time for calculation and the volume of the data increases. In some cases even the excessive quantity of data can produce unrealistic results. In other words the greater number of points does not improve the precision. The experiments show that with a certain number of points the precision really decreases. [4]
Of course, the number of the points depends on the nature of the surface. We saw that the more complex surface needs more points. For important objects such as depressions and water converging lines (stream line) we will choose more point data in order to ensure the presentation of the necessary details.
The problem with the **distribution of the points** is even more complex, especially when the collected data cannot be referred to a particular point but for an area and as a result of the interpolation a map of contour lines to be produced. GIS offers the possibility to define the centroid of every traverse. When the point data are grouped or unevenly distributed the “centroid of a cell” method is used or the “centre of gravity” method.
The **problem with the saddle points** appears when the Z-values of a pair of points are lower than a second pair, laying above them in height and located oppositely on the diagonal forming a rectangle. The solution of the problem is in the interpolation of a point with a Z-value, located among the two pairs of points and exactly at the centre of the rectangle. This is possible with the linear interpolation since the distances with weights will probably solve the problem. The computer software, however, will present two possible solutions. As a consequence of the two values of the saddle point the question is where to define the contour line. A simple way to solve this problem is to average the interpolated values obtained from the diagonally placed points. Then we place this average value at the centre of the diagonal and continue the interpolation, since now we have additional information with which to calculate the interpolation values according to Robinson.
The next problem in interpolation is characteristic only for the GIS operations and refers to the **territory where the point data are collected**. More precisely for interpolation we need interpolation points close to the edges of the explored territory. The interpolation practice shows that the best interpolation results are obtained when it is possible to search for neighborhood in all directions for choosing terrain points and defining weights, especially at the edges of the map.
The **choice of the appropriate interpolation method** is determined by multiple factors. Sometimes several methods can be applied to compare the results. The knowledge of the cartographer can also influence the choice of the interpolation method. For instance, if it is known that some objects from the surface exceed the z-value it would be better to choose the Spline method. The IDW method will give a surface that doesn’t exceed the highest or the lowest values of the z-value. IDW calculates the values of the grid cells by averaging the data of the points from each neighbouring cell. The closest point to the central one will be estimated and its weight will have greater influence in the interpolation process. IDW and Spline refer to definite interpolation methods since they are directly based in the surrounding measured values or to definite mathematical formulae that define the smoothness of the obtained surface.
The second group of interpolation methods contains geostatistical methods based on statistical models that include autocorrelation (statistical connection among measured points). As a consequence of this these methods are able not only to model a surface but also to ensure precise measurements of the predicted values. Kriging is similar to IDW in that the weights of the surrounding measured values are used for obtaining of prediction of unmeasured location. The basic formula for both interpolators is a sum of the data weights

$$Z(s_0) = \sum_{i=1}^{N} p_i Z(s_i), \qquad (1)$$

where $Z(s_i)$ is the measured value in the i-th location; p_i - the unknown weight for the measured value in the i-th location; s_0 - the predicted location; N - the number of the measured values.
In the IDW method the weight p_i depends only on the distance of the predicted location. With Kriging, however, the weights are based not only on the distance among the measured points but also on total spatial distribution of the measured points. In order to use the spatial distribution of the weights the spatial autocorrelation should be defined qualitatively. In Ordinary Kriging the weight p_i depends on the appropriate model of the measured points, the distance to the predicted location and the spatial connections among the measured values around the predicted location.

In order to do a prediction with Kriging two tasks are necessary: 1) to find the independent rules and 2) to make a prediction. In order to accomplish these tasks Kriging goes through two processes: 1) creating a diagram of the differences and the covariation functions for estimation of the statistical dependency, called spatial autocorrelation (finding values depending on the autocorrelation model i.e. the appropriate model) an 2) actual prediction of the unknown values. These two separate tasks use the data twice: the first time for assessment of the spatial autocorrelation of the data and the second time to make the prediction. One of the reasons to use the Kriging method is to avoid the influence of the accidental errors.

The geographic barriers existing in a natural landscape, such as steep rocks or rivers, create significant difficulties in the modeling of a topographic surface by means of interpolation. These barriers mark an abrupt change consequently the values on both sides differ significantly. This means that they belong to two different surfaces. For instance the values of the above sea level height change abruptly near vertical rocks. When such a surface is interpolated the points with known values at the foot of the rocks cannot be used to obtain the values of the points on the upper edge of the rock. Most interpolation algorithms allow using barriers in modeling and analyzing a surface. The barrier protects from using points from the other side of the barrier for interpolation. Consequently when using a barrier in the process of interpolation, the calculated values of unknown point are a result of the values on known points, located only at the same side of the barrier.

3. PRACTICAL APPLICATION AND COMPARATIVE ANALYSIS OF THE METHODS

In order to help the comparison of the basic interpolation methods experiments with one and the same height data have been made with different interpolation methods. Automated means for modeling the surface with contour lines have been used. All rasters are drawn with pixel size 5x5 meters in order to make comparisons. Real minimal and maximum values from the list of heights are 19.5 m and 105.5 m. All interpolation methods from ArcGIS software are used. The model is cut on a contour, defined by the final peripheral points.

TIN interpolation. The contour lines in the TIN interpolation are severely broken lines. It is obligatory to follow a procedure of smoothing the lines. The equal size of the raster cell means that the complexity of the surface should not be increased or decreased. As a whole the relief forms in the remaining methods are preserved the same as in TIN. Nevertheless it is noticed that some details, which in the TIN interpolation are formed (they are present in IDW, Spline Tension, Kriging Ordinary Spherical, Kriging Ordinary Circular, Kriging Ordinary Exponential) are lacking in both variants of Kriging Ordinary, Kriging Ordinary Gaussian and Kriging Oridnary Linear. A critical moment is point TT4 since to the east of it on the slope there are not enough measurements. Only in this method the horizontals are outlined very closely to the point.

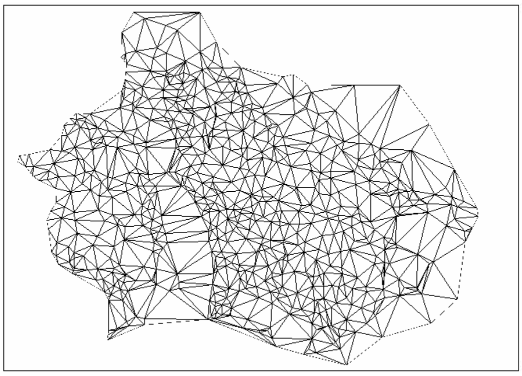

Figure.1. Data for linear TIN interpolation

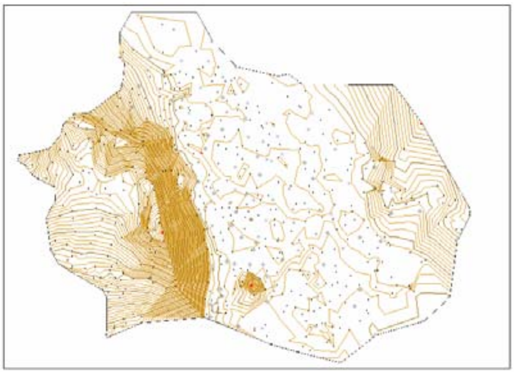

Figure.2. Contour lines, obtained as a result of linear TIN interpolation

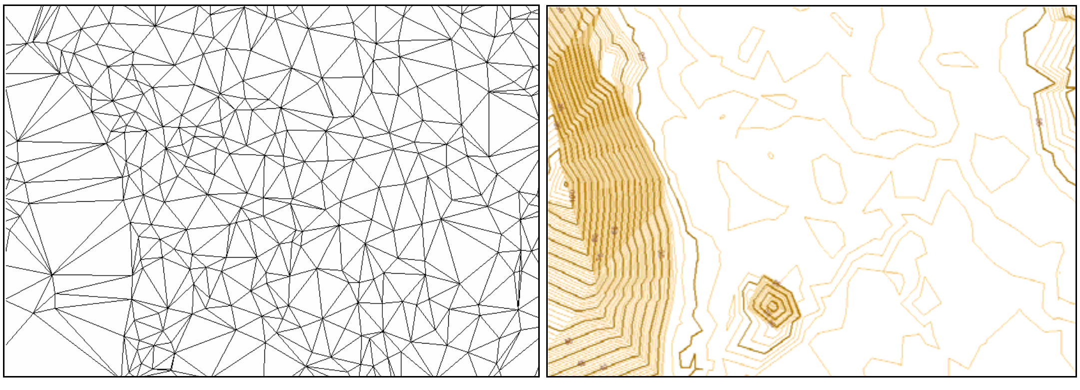

Figure.3.These two figures present outline a smaller part of the territory

IDW. H_{min} = 20m H_{max} = 105 m. The contour lines in IDW are smoother in comparison to the TIN interpolation. On the slope around the point 4 there are missing points but both methods present the horizontals in the region in a different way. The TIN interpolation presents the slope to the east smoother in comparison to the IDW, which starts right from T.T 4 and the horizontals are parallel to each other, while IDW makes a steeper swath far from the point.
The details in the TIN interpolation are not noticed in Kriging_Ordinary Linear.

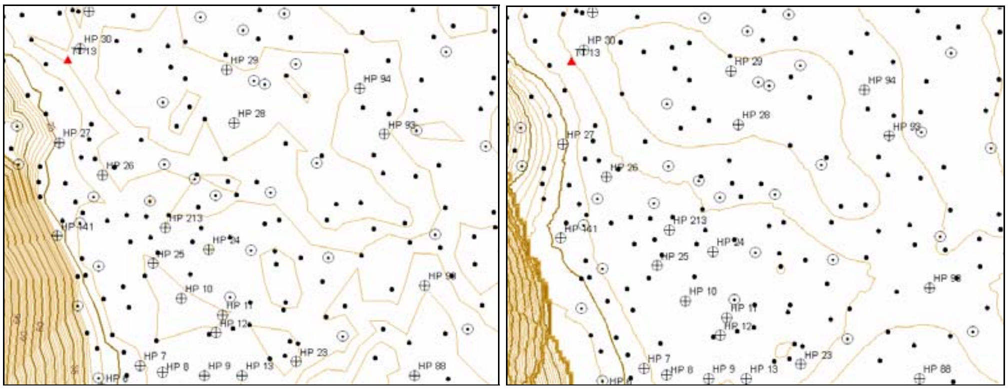

Figure.4 Comparison between (1) TIN and (2) Kriging_Ordinary-Linear

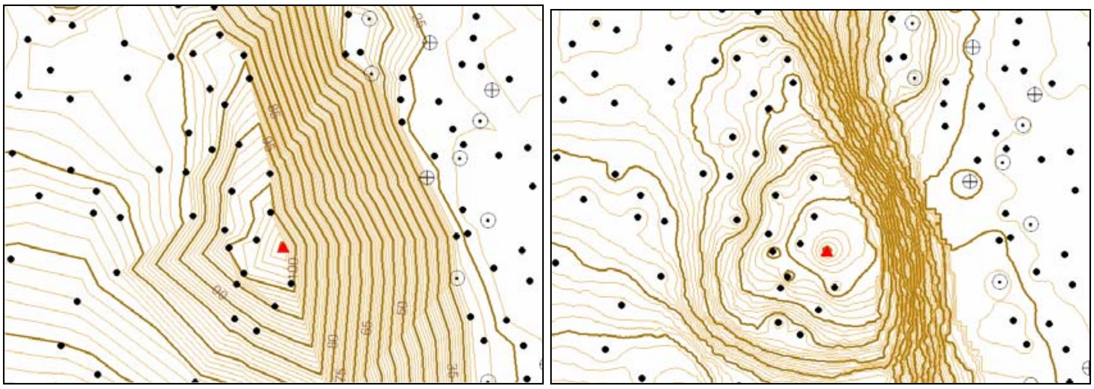

Figure.5. Comparison between 1) TIN and 2) IDW

Spline Regularized. The contour lines in Spline Regularized are rounded but an unreal minimal value is interpolated, -17, which does not exist in the list of the heights of the points. Relief shapes are formed, which are lacking in the other methods. For instance to the south-east of TT 17 two peaks are formed as well as around benchmarks 83, 84 and 87 two valleys are formed, which in reality don't exist. It is notices that the relief shapes are interpolated in a different way when the border is cut and the interpolation is carried out, and when it is interpolated without cutting the border.

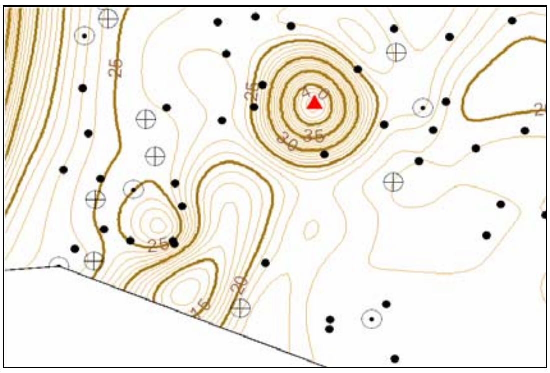

Figure.6. Spline Regularized
Here two peaks are formed to the south of TT 17.
The interpolation is done after cutting the border.

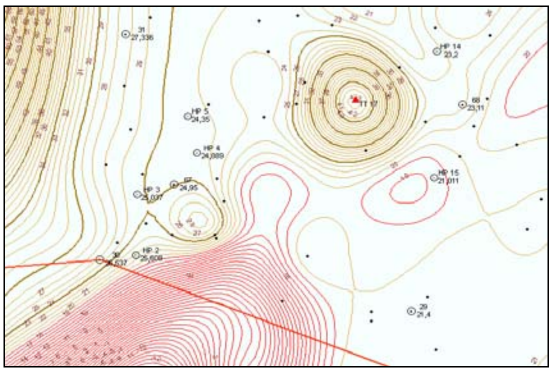

Figure.7. Spline Regularized
Here the interpolation is carried out without cutting the raster along the borderline. The shapes along the border under TT17 are different.

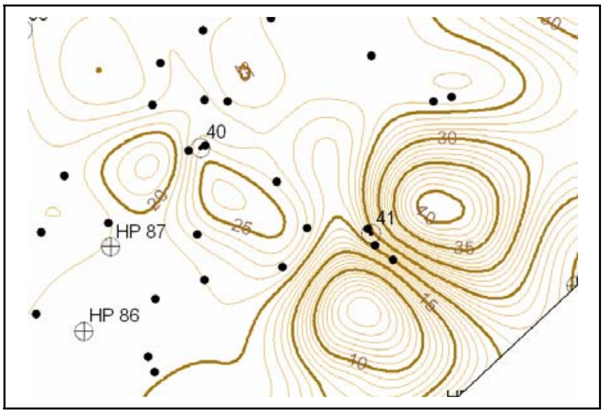

Figure 8 Spline Regularized
In HP 87 and closer to the border shapes with heights are formed, which don't exist in the list of heights of the detailed points

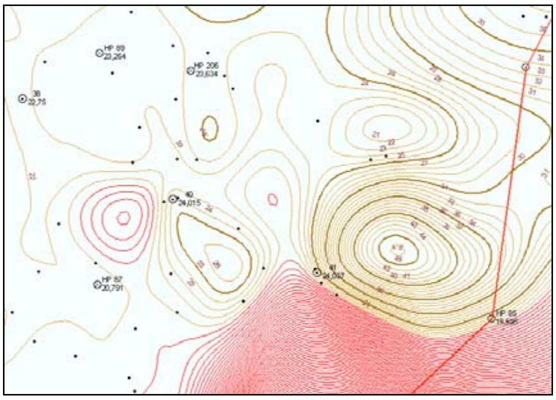

Figure 9. Spline _Regularized
Here the interpolation is carried out without cutting the raster along the borderline. The red isolines mean that the heights are not in the list.

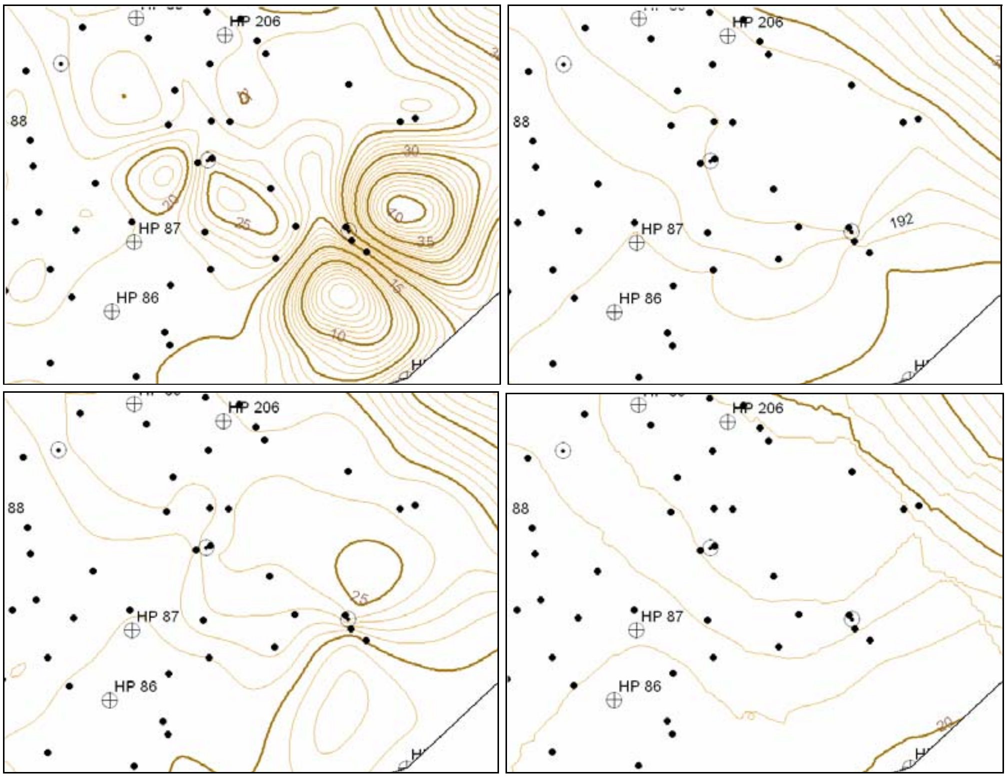

Figure 10. Comparison of: 1) Spline_Regularized; 2)Natural Neighbors 3); Spline_Tension ; 4) Kriging_Universal Linear

Spline Tension. H_{min} = 17m H_{max} = 105 m. The contour lines are closer to the other methods than to Spline Regularized.

Kriging Ordinary Shperical. H_{min} = 18.9 m H_{max} = 105 m. It is closer to Spline Tension than Spline Regularized. It is noticed that many of the small shapes in the IDW method here are united (for instance to the right of point 17)

Kriging Ordinary Circular. H_{min} = 18.9m H_{max} = 104 m = 1 m. The horizontals are wavy at some places (on the pixels).

Kriging Ordinary Exponential. H_{min} = 19.1m H_{max} = 105.4 m. Almost full coverage of the horizontals with Kriging_Ordinary_Spherical and close to Spline Tension. It is considerably different from Spline Regularized, TIN and IDW.

Kriging Ordinary Gaussian. H_{min} = 17.5m H_{max} = 100.3 m. The horizontals are wavy, very different from the other methods. The peak at TT 17 is lacking and the configuration to the right of it is completely different in comparison to Kriging Ordinary Exponential, Kriging Ordinary Circular, Kriging Ordinary Spherical and Spline Tension.

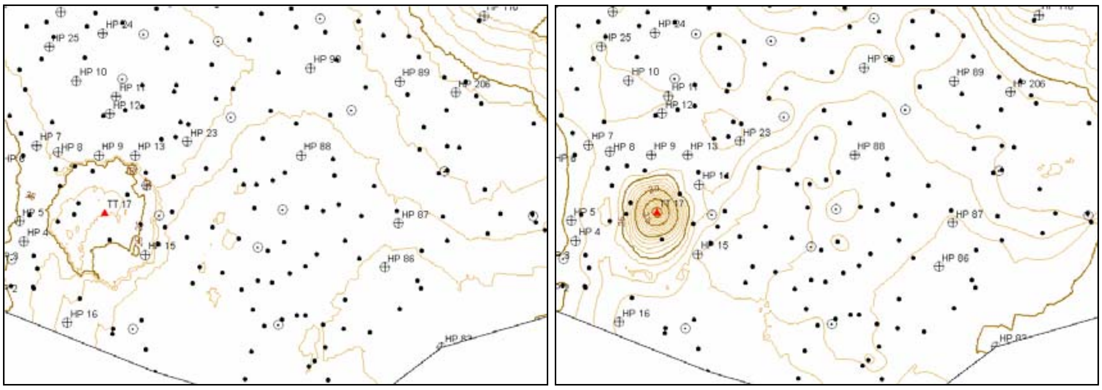

Figure 11. Comparison between 1)Kriging_Oridnary_Gaussian and 2)Kriging_Ordinary_Exponential

Kriging_Ordinary-Linear. H_{min} = 19.2m H_{max} = 102.0 m. The horizontals are smoother than the Gauss's method.
Kriging Uneversal_Linear with Linear drift. H_{min} = 10.5 H_{max} = 105.4 m. The contour lines are very wavy. The peak at TT 17 is not very well formed.
Kriging Uneversal Linear with Quadratic drift. It reads a very broad range of minimal and maximum values, which are not real and don't exist as measurements - H_{min} = 10.5m H_{max} = 105.4 m. The horizontals are very wavy.
Natural Neighbors. H_{min} = 19.5m H_{max} = 104.9 m. The lines are smoother in comparison to the universal Kriging.
About AutoCAD. It seems that AutoCAD generates horizontals only to the border of the site, limited by the triangles it creates. The disadvantages are the following:

1. There are crossing horizontals of the same name.
2. There are unclosed horizontals where it is impossible, in the interior of the site, not in the periphery.

From the comparison with the TIN-model between the two types of software it is seen that the shapes are almost the same. The advantage of the AutoCAD is that there is a procedure of smoothing the horizontals.

4. SOME COMPUTATIONS AND COMPARISONS

A special software for surface interpolation has used for this purpose. The program called SURF.

Table1.Coordinates and heights

N	Y	X	H
1	9604335.169	4676602.382	105.5
2	9604246.979	4676631.614	86.2
3	9604289.979	4676565.114	95.1
4	9604277.979	4676617.614	97.0
5	9604281.979	4676600.614	100.6
6	9604284.979	4676655.614	98.5
7	9604296.979	4676575.614	100.9
8	9604342.979	4676565.614	101.4
9	9604308.979	4676608.114	101.4
10	9604322.979	4676635.114	101.7
11	9604172.979	4676576.614	76.8
12	9604287.979	4676531.114	87.4
13	9604326.979	4676543.614	95.6
14	9604265.918	4676696.369	88.3

The coordinates and heights are extracted from the same map data. Initially we will use the first 4 points. The point 1, 2 and 3 form a triangle, the point 4 is inner one.

Table 2

From	To	Distances
1	2	92.9085
1	3	58.5751
1	4	59.1837
2	3	79.1912
2	4	34.0147
3	4	53.8540

Using different methods, we have received the next results:
WEIGHTS KRIGING:
P1 = 0.232 P2 = 0.571 P3 = 0.197 [P] = 1.000 H(4) = 92.426 m
If we use inverse distances like weights (IDW) the results are as follow:

$$P_i^{'} = \frac{1}{S_{ik}} \quad \text{or} \quad P_i = \frac{P_i^{'}}{[P^{'}]} \tag{2}$$

WEIGHTS INVERS OF DISTANCES:
P1 = 0.2604905517070975 , P2 = 0.4532391146072846, P3 = 0.2862703336856178, [P] = 1.000,
H(4) = 93.775 m(interpolated)
If we use inverse distances in power 2 like weights (IDW) the results are as follow:

$$P_i^{'} = \frac{1}{S_{ik}^2} \quad \text{or} \quad P_i = \frac{P_i^{'}}{[P^{'}]} \tag{3}$$

WEIGHTS INVERS OF DISTANCES IN POWER 2:
P1 = 0.191, P2 = 0.578, P3 = 0.231, [P] =1.000 ,H(4) = 91.940 m (Interpolated)
The results from Kriging are near to the mean arithmetic of SURF and IWD. After that we have made experiments using different surfaces. If we use surface method for a plane, defined by four points 1, 2, 3 and 4 as measured and 5 as interpolated, applied Least Squares Adjustment (LSA), we will receive:

PLANE SURFACE : H = Ao + A_1.X + A_2.Y (4)

Table 3

No	H(given)	H(calcul.)	V(difference)
1	105.5000	106.3673	0.867
2	86.2000	87.8756	1.675
3	95.1000	95.2952	0.195
4	97.0000	94.2619	-2.738
5	100.6000	94.622	5.978(Interpolated)

If we use surface in second degree, defined by more points, using LSA we will receive:

H = Ao + A_1.X + A_2.Y + A_3.X^2 + A_4.XY + A_5.Y^2 (5)

Table 4

No	H(given)	H(interpol.)	V(difference)
1	105.5000	105.1035	-0.3965
2	86.2000	90.6826	4.4826
3	95.1000	95.4427	0.3427
4	97.0000	97.1042	0.1042
5	98.5000	96.9462	-1.5538
6	100.6000	97.4014	-3.1986
7	100.9000	97.6197	-3.2803
8	101.4000	101.1920	-0.2080
9	101.4000	101.9154	0.5154
10	101.7000	104.7125	3.0125
11	76.8000	76.1222	-0.6778
12	87.4000	89.4545	2.0545

If we use surface in third degree, defined by more points, using LSA, we will receive:

$$\mathbf{H = Ao + A_1.X + A_2.Y + A_3.X^2 + A_4.XY + A_5.Y^2 + \ldots} \qquad (6)$$

Table 5

No	H(given)	H(interpol.)	V(difference)
1	105.5000	100.3195	-5.0149
2	86.2000	94.3690	-3.8829
3	95.1000	94.9762	1.4209
4	97.0000	99.4936	0.1284
5	98.5000	117.7176	-8.3237
6	100.6000	98.9603	-1.7323
7	100.9000	99.2708	-1.1125
8	101.4000	97.3343	1.5760
9	101.4000	101.9805	0.4876
10	101.7000	104.6116	0.0280
11	87.4000	65.5573	-2.3634
12	95.6000	85.8030	9.2726

M_H = 2.721 (m)

5. ADJUSTING THE SURFACE SHAPE

In order to achieve the desired result (interpretive contouring) with computer contouring, it may be necessary to introduce a bias in the choice of nearest neighbours or to introduce pseudopoints. A biased choice of neighbours is used in forming a TIN to control the grain of the final contours or to overcome a poor choice of neighbours that results from inadequate sampling of the surface. Pseudo points can be used to insure that the surface goes above or below the extreme values of the data points. It is important to carefully label pseudo points in the data base so that they will not be mistaken for real data.

6. SOME CRITERTIA FOR SELECTING AN INTERPOLATION METHOD FOR MEASURED POINT DATA

Three methods for interpolating true point data are very often used: triangulation, invers-distance, and kriging. The question, which arrives, is how does one decvide which method should be used? In [1] are considered six criteria that can be considered in selecting an interpolation method:
(1) Correctness of estimated data at control points;
(2) Correctness of estimated data at non control points;
(3) Ability to handle discontinuities;
(4) Execution time;
(5) Time spent selecting interpolation parameters;
(6) Ease of understanding.
We assume that the goal is to create an isarithmic map depicting values of a smooth continuous phenomenon. If the intention is to map various derivative measures of elevation, then triangulation is a natural choice.

Correctness of Estimated Data at Control Points

One advantage often attributed to triangulation is that estimated values for control points will be identical to the raw values originally measured at those control points: this is known as honoring the control point data. In this case, the distance between control point and grid point will be zero, and the value for the grid point can simply be made equivalent to the control point value. Although honoring control point data is worth while, using it as the key criterion for evaluating interpolation is risky for two reasons. First, the process presumes that the data are measured without error; it is common knowledge that physical recording devices are imperfect, and their reading are also subject to human error. Rather than exactly honoring control points, it makes sense that such estimates should be within a small tolerance of the raw data. A second problem with honoring control points is that the process does not necessarily guarantee correctness at non-control point locations. For example inverse-distance method provides good estimates at control points but it did poorly at non-control points.

Correctness of estimated data at non-control points

Two basic approaches have been used for evaluating correctness of data at non-control points: **cross-validation** and **data spitting**. Cross-validation involves removing a control point from the data to be interpolated, using other control points to estimate a value at the location of the removed point, and then computing the *residual*, the difference between the known and estimated control point values; this process is repeated for each control point in turn. If cross-validation is done for a variety of interpolation methods, the resulting sets of residuals can be compared. In data spitting, control points are split into two groups, one to create the contour map, and one to evaluate it. Residuals are computed for each of the control points used in the evaluation stage. One problem with data spitting is that it is impractical with small data sets because it make sense to use as many control points as possible to create the contour map. Ideally, you should use either cross-validation or data spitting to evaluate the accuracy of any contour maps that we create. Because this can be time consuming, it is useful to consider the results of those who have already don this sort of analysis. The best interpolation method depends on the yard-stick we choose. For example, triangulation produced a smaller standard deviation of residuals than an inverse-distance method (using all control points within a specified search ellipse), but the inverse-distance method minimized the size of the largest residual. Overall, some study revealed that kriging was the best, although it was only slightly more effective than an inverse-distance approach in which four control points were required in each quadrant surrounding a grid point. F. Declerc evaluated triangulation, inverse-distance, and kriging for two types of data: one relatively smooth and one more abrupt in nature. One of his major conclusions was that there was little difference in inverse-distance and kriging methods. He argued that the number of control points used to make an estimate is more important than the general interpolation method. He recommended few control points (4 – 8) for smooth data, and many (16 – 24) for more abrupt data. He also recommended not using triangulation approaches because they produce “highly inaccurate values and erratic images in poorly informed regions or with abruptly changing data”

Handling Discontinuities

In addition to honoring the data, another advantage of triangulation is its ability to handle discontinuities, such as geologic faults or cliffs associated with a topographic surface. In [3] is indicated that “If the locations of these special lines are entered as a logically connected set of points, triangulation process will automatically relate them to the rest of data.” He further indicated that although grids can handle discontinuities, recognizing a fault in gridded data is almost impossible.

Execution Time

The amount of computer time it takes to create a contour map can be an important consideration for large data sets. In general, a simple linear interpolated triangulation is faster than either inverse-distance or kriging because of the numerous computations that must be done at individual grid points with the latter methods. Kriging is especially time consuming because of the simultaneous equations that must be solved (n + 1 simultaneous equations must be solved for each grid point, where n is the number of control points). Smoothed triangulation methods, however, can take substantially longer than either inverse-distance or kriging methods [1], but it is the slowest. Given the similarity of contour maps resuling from inverse-distance and kriging, the faster execution time of inverse-distance would seem to favor it when many grid points must be computed. The usefulness of such studies, however, is problematic, as processor speeds, storage capacity, and the amount of RAM increases exponentially each year. In the end, a thorough understanding of both interpolation routines and specific nature of the data being analyzed is critical.

Time Spent Selecting Interpolation Parameters

Time spent selecting parameters refers to how long it takes to make decisions such as the appropriate power for distance weighting, the number of control points to use in estimating a grid point, which model to use for the semivariogram, or which smoothing method to use for triangulation. One can avoid this time by simply taking program defaults, but such an approach is risky. Kriging is the most difficult in this regard because of the need to consider whether one or more semivariograms are appropriate and what sort of model should be used to fit each semivariogram. The time spent selecting parameters will obviously become longer if one wishes to evaluate correctness using cross-validation or data spitting. This time can be eliminated by using the evaluations of others, such as those described previously, although more studies appear necessary to cover the broad range of data types that geoscientists are apt to deal with. Ease of understanding refers to the ease of comprehending the conceptual basis underlying the interpolation method. Clearly, kriging scores poorly on this criterion, as the kriging literature is often complex.

Ease of Understanding

Although automated interpolation is desirable because it eliminates the effort involved in manual interpolation, some study illustrated some potential limitations of automated interpolation. Some authors [5] compared automated and manual interpolation of two data sets. These data were automatically interpolated via kriging and manually interpolated by experts. A quantitative analysis using data splitting revealed that the computer-interpolated precipitation map was significantly more correct than the manually interpolated one, and that there was no significant difference in computer and manually interpolated bedrock-surface maps. Together these results suggested that the computer-interpolated maps were at least as good as, if not better than, the manual ones.
Comments elicited from experts, however, raised serious questions about the appropriateness of automated interpolation. Criticisms noted by experts can be understood by comparing the computer-interpolated map of the storm even with a couple of manually-interpolated maps created by the experts. The most significant problem noted by experts was that “isolated peaks and depressions overly smoothed and too circular.” A second problem was that the computer-interpolated map portrayed “features not warranted by the data points”. Other problems noted by experts on the computer-interpolated map included “jagged lines” and “spurious details”.

7. CONCLUSION

As it is seen there is a rich variety of interpolation methods and the correct choice in their application is especially important. But a very important conclusion is: The detailed (measured) points should be chosen on the terrain very carefully. They should be located on the picks, the dips, watershed divide (ridge line) and water or stream lines (valley lines), where the slope of the terrain is changing, and should be peak, valley and saddle points. If this condition is not fulfilled, none of the methods renders good results. The different methods give different, most often incorrect and in some cases absurd results. It is appropriate the interpolation to be carried out according to two different methods, to analyze the differences and also the obtained graph should always be visually controlled.

REFERENCES

1. Demers S. (1989) *Fundamentals of Geographic Information Systems. (2nd ed.).* John Willey&Sons, New York
2. Longley P., Goodchild M., Maguire D. (2001). *Geographic Information Systems and Science.* John Willey&Sons, New York
3. Richard H. Groshong, Jr**.** *3-D Structural Geology***,** Second Edition, Springer-Verlag Berlin Heidelberg 1999, 2006
4. Robinson A., J. Morrison, P. Muehrcke, Kimerling A., Gupttile S. (1995). *Elements of cartography (6th ed.).* John Willey&Sons, New York
5. Slocum T., McMaster R., Kessler F., Howard H. *Thematic Cartography and Geographic Visualization.* 2nd ed. Pearson Prentice Hall. 2005.
6. Valev G.**,** Kastreva P. Application of the interpolation methods in the modeling of a topographic surface*. International symposium “Modern technologies, education and professional practice in geodesy and related fiels”,* Sofia, 5 -6 November 2009

AUTHORS:
Prof. DSc. Eng. George Valev
University “Ep. Konstantin Preslavski”
Shumen, Bulgaria
E-mail: valev@techno-link.com
Assos. Prof. Dr. Eng. Penka Kastreva
South-West University “Neofit Rilski”
Blagoevgrad, Bulgaria
E-mail:penkakastreva@gmail.com