

---

## EVALUATION AND SETTING OF PARAMETERS IN INTERPOLATING METHODS BY MODELING OF DIFFERENT TYPES OF GEORELIEF

Jana Kadlčíková<sup>1</sup>, Pavel Tuček<sup>2</sup>

<sup>1</sup>Katedra geoinformatiky, Přírodovědecká fakulta, Univerzita Palackého,  
tř. Svobody 26, 771 46, Olomouc, Česká republika  
jana.kadlcikova@centrum.cz

<sup>2</sup>Katedra geoinformatiky, Přírodovědecká fakulta, Univerzita Palackého,  
tř. Svobody 26, 771 46, Olomouc, Česká republika  
tucekp@inf.upol.cz

**Abstract.** The aim of the article is the introduction to the methods for testing of hypothesis in order to choose the most suitable interpolating method (and the parameters setting) for the computation of the most precise digital elevation models (DEM) based on the type of georelief.

**Keywords:** DEM, interpolating methods, quality of the DEM, georelief

### 1 Introduction

It is possible to estimate the dependency between the interpolating method and the type of the georelief due to the quite long process of the testing and evaluating of different types of interpolating methods and their parameters setting (Software environment ArcGIS v. 9.2). It is also possible to estimate the most suitable methods and optimal setting of their parameters in order to reach the best result by modeling the plains, wold, highlands or mountains. The results of the testing should become the background for the next advanced computation of the most precise values of the morphometric attributes by the different types of the relief, because the accuracy of the input data has the essential influence on the resulting DEM.

### 2 Data, preprocessing and processing

Interpolating methods and obviously the setting of their parameters were tested on 8 trial terrains with the different type of the georelief: plain, flat wold, rugged wold, flat highlands, rugged highlands, flat mountains and rugged mountains and also the gap on the level of different types of geomorphological segmentation of the relief. Input data were the layers of contour lines DMÚ 25, which were obtained from the department of geoinformatics at the Palacký University in Olomouc and the research grant MŠMT with the name “Dynamical Geovisualization in Critical Management” solved at the institute of geography at the Masaryk University in Brno. The preparation, preprocessing and processing of the data were performed in the software environments ArcGIS v. 9.2 and ArcView GIS v. 3.2.

The area 2 x 2 km was selected from each type of the relief for the testing of the parameters setting. The segmentation of the relief has been conserved in each above mentioned area, see the table 1.

**Table 1.** Chosen areas, based on the different type of relief and their segmentation in the tested area 2 x 2 km

| Type of the relief | Segmentation (m) | Area                   | Minimum (m) 2 x 2 km | Maximum (m) 2 x 2 km | Segmentation 2 x 2 km (m) |
|--------------------|------------------|------------------------|----------------------|----------------------|---------------------------|
| Plain              | 0-30             | Zerotinska plain       | 245                  | 260                  | 15                        |
| Flat wold          | 30-75            | Orlovska table         | 255                  | 300                  | 45                        |
| Rugged wold        | 75-150           | Vlcnovska wold         | 225                  | 365                  | 140                       |
| Flat highlands     | 150-200          | Divacka highlands      | 220                  | 385                  | 165                       |
| Rugged highlands   | 200-300          | Hostalkovska highlands | 365                  | 590                  | 225                       |
| Flat mountains     | 300-450          | Rusavska mountains     | 375                  | 730                  | 355                       |
| Rugged mountains   | 450-600          | Hornoopavska mountains | 745                  | 1200                 | 455                       |
| Gap                |                  | Pozlovska gap          | 250                  | 395                  | 145                       |

The buffer in the length 100m was created around the polygon 2 x2 km after the selecting of the area with the demanded segmentation. The next step were the selecting of the contour lines from the data DMÚ 25 and the conversion to the point layer (it is necessary for the input for the interpolation).

Reference points were obtained from the altitude points. Test file with the demanded count of numbers (the value corresponds to the maximal value for the count of points in the layer) was generated with the help of the Random Number Generator (application of the Visual Basic 6.0). The generator requests the count of points from the given layer and the demanded portion of the reference points from this amount (10% in our case). This text file was imported to the MS Excel. Names “ref\_id” and “reference” (with the value 1) were filled in. The last step was the saving to the DBF format and connection to the original layer with the help of the field “ref id” and the field with the “unique\_id” (original point layer). Points with the value “1” in the reference field were chosen with the help of the attribute query and saved to the layer “reference\_points”, the others were saved to the layer “input\_points”.

Eight different types of the relief with the different segmentation and different density of the input points were tested. The density and regular spacing of the input points decrease from the rugged to the plain relief. It is possible to assume, that the smoother surfaces need different setting of the input parameters than the other surfaces.

The criteria for the selection of the value for the parameters “Input points” were the testing the different number of input points. The first value was set to 3 (two points is the linear interpolation) and the last value was set to 50 in order to compute also with the outlying points. Similarly for the second parameter (weight – spline, power - IDW) were tested recommended values [1], limit values (for the weigh of regularized spline it is from the interval <0;1>) or non typical values (for the power of the IDW method is the typical value 2 [1]) in order to observe the possible applicability of the method for the different type of the relief. The result of the whole testing is the declaration of the values for the setting of the parameters in order to reach the best results by the modeling of the DEMs.

848 DEM for 8 above mentioned areas were generated from the layers of the input points. The values of the parameters, which have been used for the modeling, are written in the table 2. The size of the pixel was set on 5m (it corresponds to the interval of the contour lines in DMÚ 25). Parameters were combined in order to reach the best results (example: Method of spline with tension with the count of input points 3. The weights were set on 0,1,5,10,15,20 a 50).

**Table 2.** Settings of parameters in the interpolating methods and computation of DEM

| Method                 | IDW                      | Regularized spline     | Spline with tension         |
|------------------------|--------------------------|------------------------|-----------------------------|
| Number of input points | 3, 5, 10, 15, 20, 30, 50 | 3, 5, 10, 15, 20, 30   | 3, 5, 10, 15, 20, 30        |
| Power                  | 0.5, 1, 2, 3             | -                      | -                           |
| Weight                 | -                        | 0, 0.01, 0.1, 0.5, 0.9 | 0, 1, 5, 10, 15, 20, 30, 50 |

Resulted digital elevation models were trimmed to the size 2 x 2 km in order to prevent the errors caused by the interpolation at the boundary. Reference points were also trimmed to the size 2 x 2 km, converted to the raster with the pixel size 5 m. All has been used for the computation of the RMSE.

### 3 Interpolating Methods

Interpolating methods IDW, regularized spline and spline with tension were used for modeling of different types of relief. Additional parameters were changed in order to reach the best result. All above mentioned methods are introduced in the next paragraph.

#### 3.1 IDW - inverse distance weighting

The basic theory of this method is so called “First Geographical Rule”: “The closer the things are, the bigger the relationship between them is.” [3]. This method is used for the evaluation of the altitude with the help of weighted mean of the altitudes of the points which are close to the unknown point. IDW method is the local interpolation method. [4].

The basic input parameters are power and the count of the input points. The parameter power make the user possible to handle the influence of the known points to the interpolating value based on the distance from the output point. The bigger the value is, the bigger is the influence of the nearer points and the surface will have more detail (be less smooth). The smaller the value is, the smaller is the influence of the nearer points and the bigger is the influence of the outlying points. The surface is therefore smoother. In the case of “power = 0” the resulting value is equal to the arithmetic mean of the included points [1].

The character of the interpolating surface could be also limited by the incoming points for the computation of each point. The input could be conditioned by the number of input points or by the usage of the radius.

#### 3.2 Spline

The spline method uses the mathematically defined curve, which interpolate each part of the surface part to part. The usage of the spline method depends on two conditions: the surface must pass exactly through the data points and the surface must have the minimal curvature

(cumulative sum of squares of the second derivation need to be minimal). [1].

The resulting surface is often very smooth due to the smoothing effect. This is the reason, why this method is more suitable for the interpolation of the flat surfaces (phenomena) [4]. It is the local interpolation method.

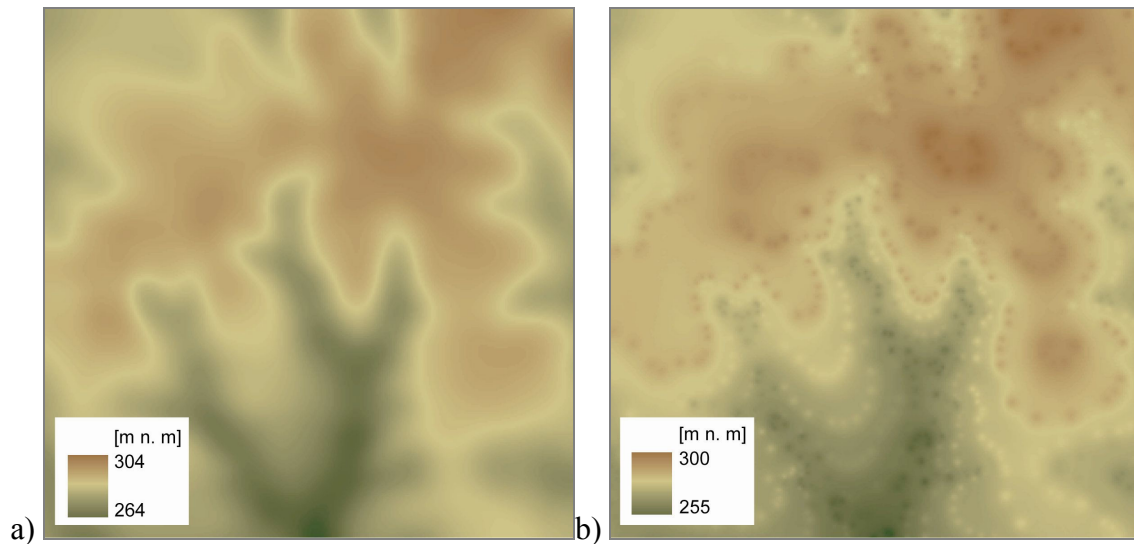
There exist two method of spline interpolation in the software environment ArcGIS v 9.2.: Regularized spline and the spline with tension. The first one method is suitable for the modeling of the smooth surface. The result is the smooth surface with the stepwise changing values, which can possibly be out of the data range. There is the option to choose the value of the parameter, which represents the weights for the third derivations and it leads to the minimalization of the torsion. The value of the weight is the request to the smoothness of the surface. Typical settings are: 0, 0.001, 0.01, 0.1 a 0.5 [1].

The method spline with tension influences the rigidity of the surface according to the character of the model phenomena. It generates the less smooth surface with more data in the data range. The settings of the parameters represent the values of the weights again. The weights represent the value of the tension which leads to the minimalization criteria obtaining the first derivation. The bigger is the value of the weight, the rougher is the resulting surface. Typical settings of the weights are: 0, 1, 5 a 10 [1].

#### **4 Evaluating of the resulting DEM, based on the different settings of the interpolating methods.**

The quality of the DEM depends on the data source and the method of interpolation. Systematic and unsystematic errors can occur during the process of the DEM making. These errors can negatively influence the next computation of the morphometric attributes. There exist three kinds of errors: (i) errors caused by the user, (ii) systematic errors and (iii) random errors or noise, which can not be clean up.

There exist couple of methods for the determination and the reduction of the inaccuracy in the DEM. The fast way how to uncover the majority of the errors is the visual control of the DEM (fig. 1). This leads to the recognition of the errors caused by the deficient in the vertical resolution and the problems caused by the local abnormality [2]. There are also other way how to compare more sophisticated the resulting DEM. These methods are based on the statistical approach. The fundamentals of these methods lie in the use of the standard deviation, mean, minimal and maximal value and RMSE, hammock plot or the computation of the hammock index.



**Fig. 1.** Examples of two DEM (with the type of the relief: flat wold – Orlovská table). It is possible to make the visual identification of a) minimal number of rough errors (method spline with tension with the weight 15 and the number of input points 30) and b) many rough errors (method IDW, power 2, number of input points 50).

The most frequented measure of uncertainty is the *root mean square error* - *RMSE*. It measures the variation of the variation rate between original altitude data and the data of the DEM. The mathematical formula for the RMSE could be written as [5]:

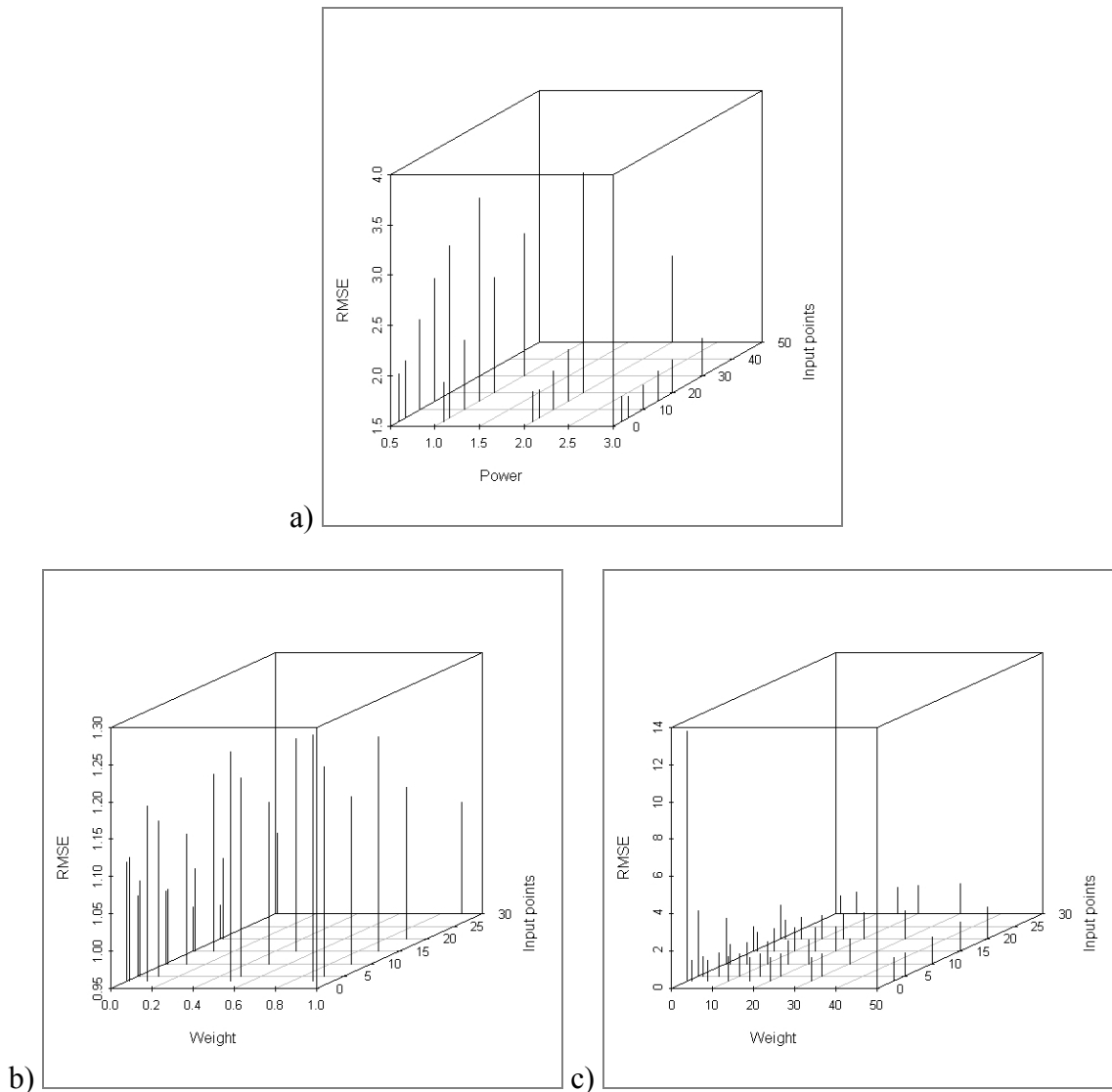
$$RMSE_Z = \sqrt{\frac{1}{n} \sum_{i=1}^n (Z_{di} - Z_{ri})^2}$$

where:  $Z_{di}$  is the value of the altitude computed from the DEM

$Z_{ri}$  is the corresponding original altitude.

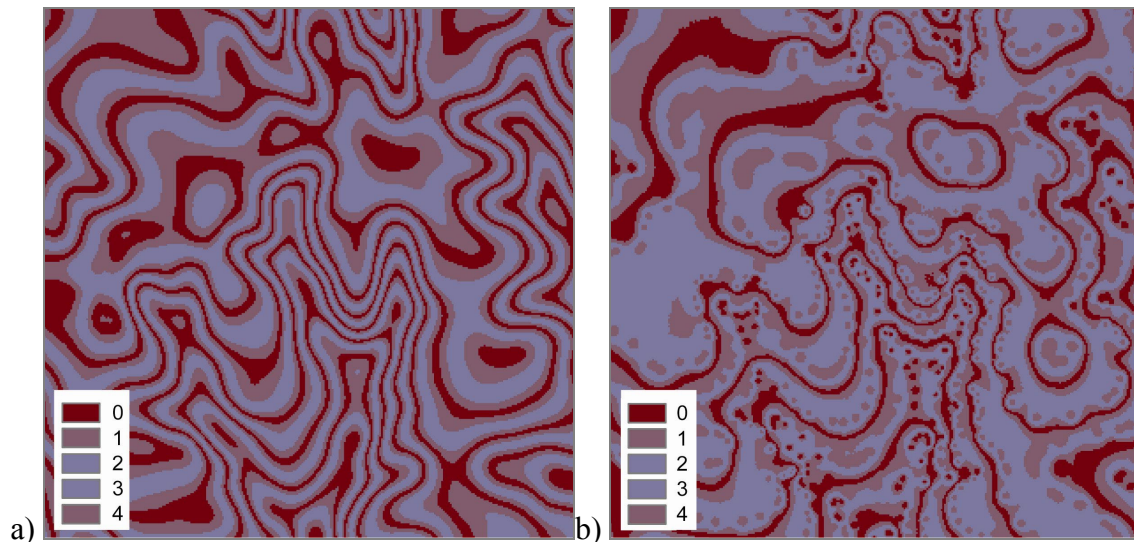
$n$  is the number of the controlled points

Bigger value of the RMSE represents the bigger variance between two datasets. The ideal value should not go over the half of the interval value of the original contour lines. The example of graphic representation of the RMSE dependence on the input parameters is shown in the figure 2. The biggest advantage of the RMSE is the easy use and computation. This index is on the other side only the measure of the variance and this is the reason why it is not able to interpret the spatial change of the errors over the interpolated surface. The better one method for the understanding and quantification of the DEM quality is the hammock plot (especially in the case of the data, which come from the contour lines).



**Fig. 2.** Examples of three graphs that represent the dependence of RMSE on the input parameters (the type of the relief: flat wold – Orlovska table) for a) IDW method, b) method regularized splilne and c) method spline with tension. The value should not go over the half of the interval value of the original contour lines, in this case over the value 2,5.

*Hammock plot* is the surface, which arise out of the integer dividing of the original DEM values. The aliquot is the value of the interval range in the dataset of the original contour lines. This is the way how the errors caused by the interpolation can be detected. These errors represent the redundant occurrence of the pixels which correspond to the original contour lines. – i.e. pixels with the residual equals to zero. (fig 3).



**Fig. 3.** Examples of two hammock plots from the DEM with the type of relief: flat wold (Orlovska table) which represents particular residuals (dividing by 5 – mod(5); 5 = interval range of the original contour lines) – red mod0, violet mod1 a mod4, blue mod2 a mod3. a) hammock plot DEM generated from the method spline with tension (weight 15, number of input points 30) a b) hammock plot DEM generated from the method IDW (power 2, number of input points 50).

Hammock plot is the principle of the next characteristic – *hammock index* ( $H$ ), which shows the stable of the module (outcoming residuals). Its value lies in the interval  $\langle -1, 1 \rangle$ . Ideal value is 0. The mathematical formula of the hammock index can be written as [5]:

$$H = \frac{(nf_0) - \sum_{i=1}^{n-1} f_i}{\sum_{i=0}^{n-1} f_i}$$

where:  $n$  is the interval of the contour lines

$f_0$  is the frequency of the mod0 (frequency of the pixels with the residual 0)

$f_i$  is the frequency of the others mod

## 5 Conclusion

The most suitable method was selected for each area after the comparison of all DEM according to the above mentioned methods of evaluation. The settings for the method is shown in the table (tab. 3). It is possible to say that the method spline with tension is the most suitable method for all possible types of the relief. The possible setting of the weights can be resulted in the more or less smooth surface.

This method is generally suitable for the relief interpolation from the altitude points [1]. This assumption was used during the testing of the methods. The values of the parameter “Input points” stayed without changes for all types of the relief (20-30). Bigger values of this parameter resulted in the unfaithful interpolation, caused by the computation with the outlying points. The decreasing trend has been observed by the setting of the parameter “Weight”. The

flatter the relief is the smaller should be the value of the parameter “Weight” (5-15). On the other side, the more rugged is the relief the bigger value of the parameter “Weight” should be set (20-30).

**Table 3.** Most suitable method and its setting for the quality DEM.

| Type of the relief | Interpolating method | Number of input points | Weight |
|--------------------|----------------------|------------------------|--------|
| Lowland            | spline with tension  | 30                     | 5-10   |
| Flat wold          | spline with tension  | 20-30                  | 10-15  |
| Rugged wold        | spline with tension  | 20-30                  | 5-10   |
| Flat highlands     | spline with tension  | 30                     | 10-15  |
| Rugged highlands   | spline with tension  | 30                     | 10-20  |
| Flat mountains     | spline with tension  | 20-30                  | 20-30  |
| Rugged mountains   | spline with tension  | 15                     | 20-30  |
| Gap                | spline with tension  | 20-30                  | 1-5    |

The main output of the testing is the design of the parameters setting, which should make the decision during the DEM making easier. Such DEM is more suitable for the computation of the morphometric attributes, for the modeling of the spatial phenomena and processes or as a ground for the geomorphologic studies. Original testing was performed on the 8 areas. More objective results can be reached after the testing on more sample areas. It is necessary to make the comparison. The final step should be the estimation of the trend.

## References

1. ArcGIS desktop help – Working with Spatial analyst
2. Gallant, J. P. - Wilson, J. C. *Terrain analysis – Principles and applications*. New York, 2000.
3. Tober, W. A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46, 2. 1970.
4. Voženílek, V. et al. *Integrace GPS/GIS v geomorfologickém výzkumu*. Vydavatelství UP, 2001, Olomouc.
5. Wood, J.D. *The geomorphological characterisation of digital elevation models*. Geography Department, University of Leicester, UK, unpublished Ph.D. dissertation. 1996, dostupné také z [http://www.geog.le.ac.uk/jwo/research/dem\\_char/thesis/](http://www.geog.le.ac.uk/jwo/research/dem_char/thesis/)