

## APPLICATION OF SURFER SOFTWARE IN DENSIFICATION OF DIGITAL TERRAIN MODEL (DTM) GRID WITH THE USE OF SCATTERED POINTS

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### Summary

This article explores the problem related to preparing the digital data used for 3D visualizations on big areas. Because of the frequent problem of having only a small amount of such data the authors introduce a technology allowing densification of the data that make up the Digital Terrain Model. This is where SURFER software finds its application. These methods are sufficient to generate images for landscape visualization.

### Keywords

landscape • visualization • Digital Terrain Model (DTM)

## 1. Introduction

### 1.1. Data

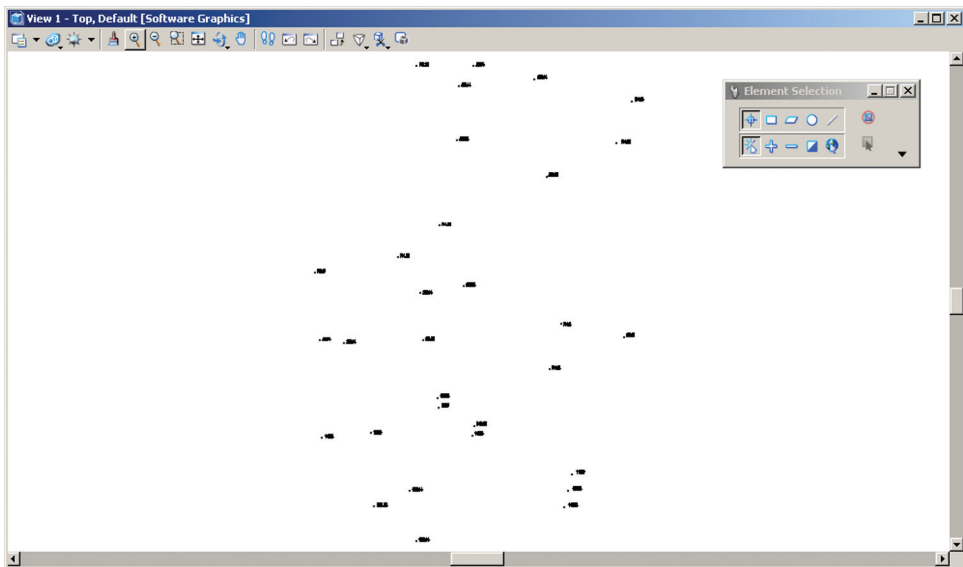
Landscape visualization is one of the specific tasks of 3D modeling. This problem requires preparation of data that allows visualization of very big areas. An additional obstacle in data preparation is the necessity to “grasp” the horizon, not only from the point of view of an observer on the ground, but also from the bird’s eye view. We do not always have the possibility to collect satisfying data which would reflect the realism of the space surrounding us [Wytyczne... 2003a, b]. However, we very often have partial data. Data can be obtained in different ways. In cases where no digital data is available, it can be obtained directly from analog maps. In such situations there is a necessity to prepare the materials in a manner that would prevent the 3D model of the space surrounding us, from having unnatural terrain forms such as sudden terrain shifts or terrain discontinuities. One of the better solutions is densification of terrain points with “artificial” coordinates, calculated basing on the XYZ data. It can be performed in many ways. In this article, the suggested solution is the use of SURFER software.

## 1.2. Description of SURFER software

SURFER software is a product of Golden Software, Inc. and finds its use among others in creating representations of terrain surface. With its use, one can for example generate isoline maps, 3D maps, create sections of 3D maps, and calculate volumes and surface areas. Generation of such maps requires an algorithm, which will prepare the data for 3D visualization in a form of a map, basing on the input data (in most cases measured XYZ coordinates of points).

SURFER software uses a regular grid of points called GRID. This feature is used for processing insufficient amounts of input XYZ data and preparing them for later use in visualization module.

During data preparation there is a possibility to preview an approximated form of a 3D map.



Source: own study

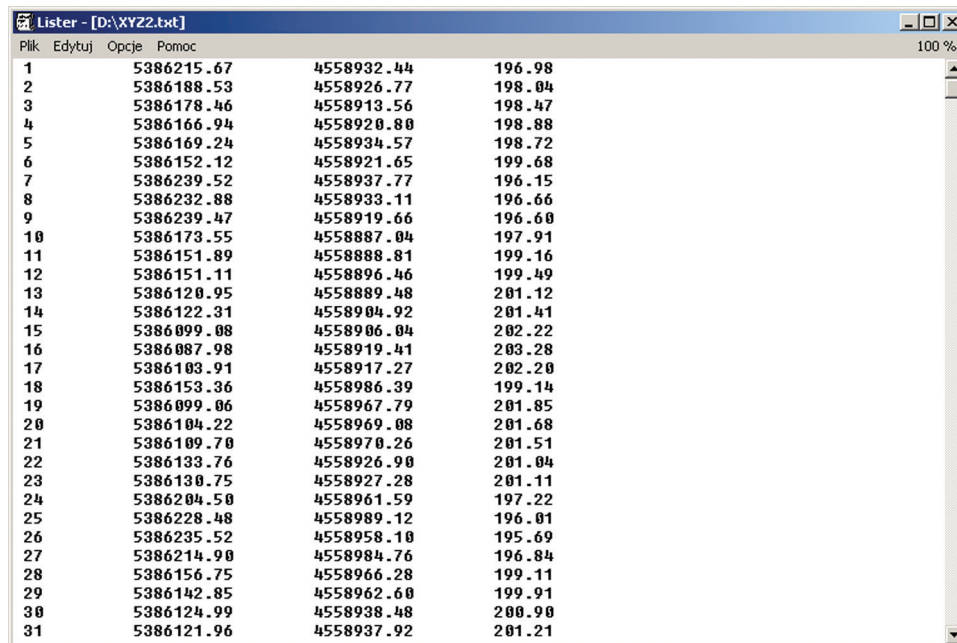
**Fig. 1.** An example of XYZ measurement data

The SURFER package offers many methods of interpolation to determine the elevation of grid nodes. The adapted calculation algorithms allow choosing the most suitable ones, depending on the XYZ input data, its quantity, density or distribution.

## 1.3. Regular grid of values

SURFER software operates on a regular grid of XYZ values. This means that the interval of grid's element in the direction of the X axis is always constant. This is

also applicable in the direction of the Y axis. Both axes may have different intervals, dependent on the individual settings of the user.



	Plik	Edytuj	Opcje	Pomoc
1	5386215.67	4558932.44	196.98	
2	5386188.53	4558926.77	198.04	
3	5386178.46	4558913.56	198.47	
4	5386166.94	4558920.80	198.88	
5	5386169.24	4558934.57	198.72	
6	5386152.12	4558921.65	199.68	
7	5386239.52	4558937.77	196.15	
8	5386232.88	4558933.11	196.66	
9	5386239.47	4558919.66	196.60	
10	5386173.55	4558887.04	197.91	
11	5386151.89	4558888.81	199.16	
12	5386151.11	4558896.46	199.49	
13	5386120.95	4558889.48	201.12	
14	5386122.31	4558904.92	201.41	
15	5386099.08	4558906.04	202.22	
16	5386087.98	4558919.41	203.28	
17	5386103.91	4558917.27	202.20	
18	5386153.36	4558986.39	199.14	
19	5386099.06	4558967.79	201.85	
20	5386104.22	4558969.08	201.68	
21	5386109.70	4558970.26	201.51	
22	5386133.76	4558926.90	201.04	
23	5386130.75	4558927.28	201.11	
24	5386204.50	4558961.59	197.22	
25	5386228.48	4558989.12	196.01	
26	5386235.52	4558958.10	195.69	
27	5386214.90	4558984.76	196.84	
28	5386156.75	4558966.28	199.11	
29	5386142.85	4558962.60	199.91	
30	5386124.99	4558938.48	200.90	
31	5386121.96	4558937.92	201.21	

Source: own study

**Fig. 2.** An exemplary file containing coordinates Number X Y Z

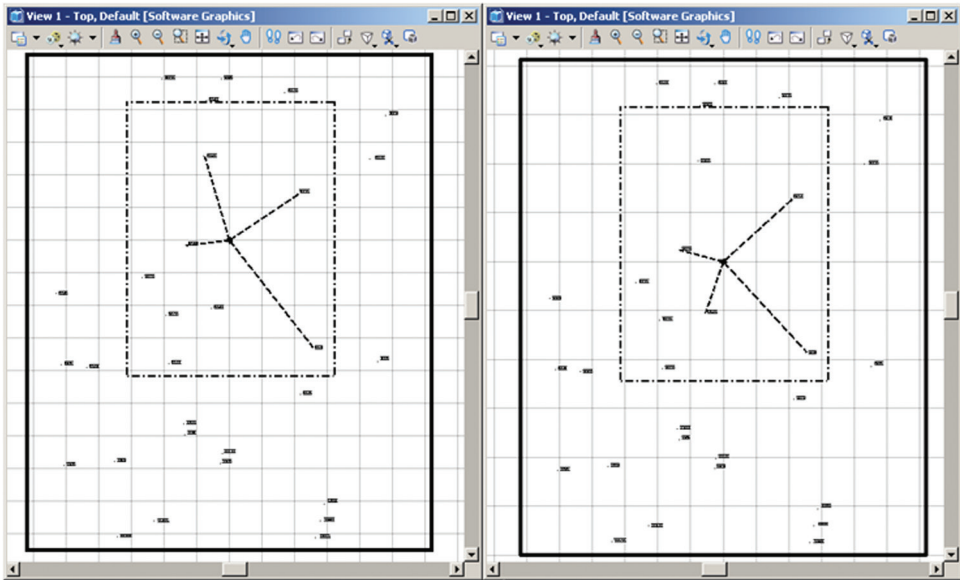
The main goal of developing a GRID is to establish a surface composed of regularly distributed XYZ points in such a way, that the input points would be contained within.

The most important task is determining the vertical coordinate. This is done by using the interpolation or extrapolation method. Interpolation can be done in many ways.

Unfortunately, extrapolation does not always give the desired results. However, in the case of preparing the required data for visualization on big areas, we have to use this method. This limits the number of ways in which the regular grid of values can be created.

A significant part of the job is developing a GRID. One of the key parameters is the investigated range of node surroundings, which implies selection of the points in the set of input data. To calculate the vertical coordinate in the grid eye, the key data (apart from the point elevation) is its distance from the node.

It determines the degree in which the value of the function, in the point of input data is reflected on the point elevation in the grid node.



Source: own study

**Fig. 3.** The main idea of creating a GRID elements having uniform and non-uniform interval

The value of the function in the node point located in  $(i, j)$  position can be expressed by the following formula:

$$Z_{i,j} = w_1 \cdot z_1 + w_2 \cdot z_2 + w_3 \cdot z_3 + w_4 \cdot z_4 \quad (1)$$

where:

- $Z_{i,j}$  – value of the function in the node located in  $(i, j)$  position,
- $z_{1-4}$  – value of the function in exemplary points 1–4, taken from the input data set,
- $w_{1-4}$  – weight coefficients in the points 1–4, taken from the input data set.

The weight coefficients determine the influence of the elevation taken from the data points on the value of the function on the calculated node located in the position of the  $Z_{i,j}$  point of the GRID.

For the purposes of this study the assumed test quantity of the points is 4. It can be selected in a wider range. However, one should remember the calculations will be much longer in case of very big areas that contain a large number of nodes.

#### 1.4. Input data verification

A separate problem is the process of data filtering. Its aim is to eliminate incorrect points from the set of input data. To verify the set of input data it is recommended

in the beginning to generate a report regarding the basic statistics of the data. Then, based on the report, we can determine if the set of input data contains potentially incorrect information.

Because there is a possibility of errors that are duplicated X Y coordinates, the program eliminates them. This is a necessary step for algorithms for GRID development. Another possibility is having incorrect data in the set because of the range of investigation. The program also offers a possibility to filter the coordinates with an option to determine the acceptability of the data.

The data excluded from the interpolation can be later defined according to X, Y and Z axes. The rules of exclusion are defined as complex logical operations.

## 2. GRID generation

### 2.1. Selecting the interpolation method

Properly prepared and verified input data is the basis for creating a regular grid of values GRID. The SURFER software offers 12 methods of grid generation to choose from. Because of the large number of interpolation methods, one should keep in mind a few basic criteria while choosing, such as: number of input points, area of elaboration or necessity of extrapolation. Additionally, each of the methods has its own set of parameters [Galon 2009].

For the purposes of the presented method of calculating data for densification of grid XYZ points, we are basing the GRID on the Kriging method, as a default method of GRID development. However, another criterion that had to be taken into account was the amount of input data. In case of insufficient data, a more reliable interpolation method would be used, for example the Polynomial Regression method.

While creating a GRID, the SURFER software can take into account the edges of discontinuity. The program offers two methods: Breaklines and Faults. Both are used for the same purpose.

The Faults method sharpens the generated model while Breaklines generates smoother forms. During calculations the Faults algorithm does not intersect the edges of discontinuity, it omits them instead. This results in an increase of the distance between the determined grid point from the known point. It decreases the weight of this point which influences the final calculation of the vertical coordinate.

The Breaklines algorithm uses the elevation obtained from intersecting the edge of discontinuity with the line drawn from the grid node which has known coordinates. Both of these methods require different input data formats. For the Faults method the XY coordinates of the edge are sufficient. The Breaklines method requires in addition defining of the vertical Z coordinate.

All this information has to be loaded into the program in a form of a text file, in which we define the coordinates of the edge of discontinuity of the terrain. Unfortunately, not all of the interpolation methods allow for applying the technology of defining areas of discontinuity. Lack of it results in flattening of the model, which

in case when very faithful representation of the area is desired, limits the selection of interpolation method.

## 2.2. Interpolation quality evaluation

When we have to test several interpolation methods in order to select the best one or to select the proper parameters, we can use the interpolation evaluation [Longley et al. 2006]. The main idea is to build a grid and then to interpolate the heights for data points basing on the generated grid. The deviations from the real values inform us about the precision of the generated model.

We can test all the points or only a part of them. For large sets of data it is recommended to test only a part of them by providing proper information in the field *Number of random points to validate*. There is an additional filtering option, which allows limiting the range by minimum and maximum coordinates X, Y, Z – *Select validation points within these limits*. The results of the report are saved in a text file. The basic parameters for the grid interpolation are:

- the average error,
- the standard deviation,
- the variance.

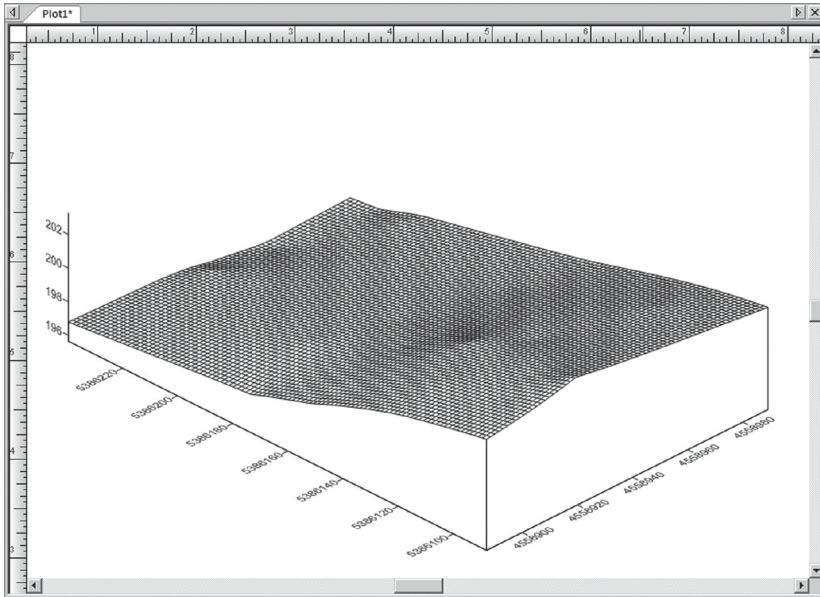
## 2.3. Interpolation grid data

Using the program options we have a possibility to change the density of grid elements. The software automatically calculates the range of minimal X and Y coordinates. One should remember to operate these parameters in balanced way. This data will be used later for creating the DTM in the following steps of the developed technology.

A grid that is too dense can contribute to a necessity of using fast computational units and a large amount of operational memory. To use the GRID in generating a DTM in different systems we have to be able to use its data. The simplest way is to save it in a text file with a space separator.

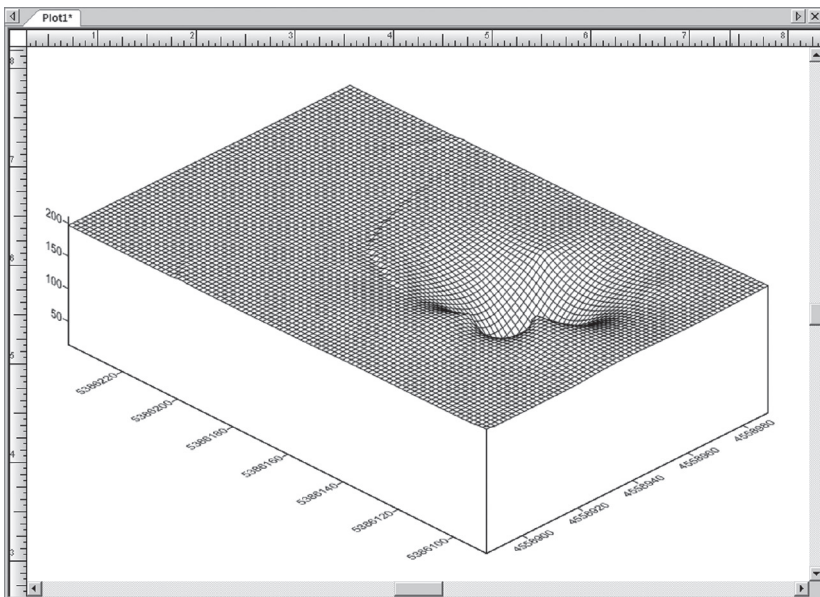
## 2.4. A quick preview of the results of calculations

Before exporting the data to a text file, it is recommended to use the results of calculations to visualize the grid (3D Wireframe feature in the SURFER software). Quite frequently, such a procedure gives us sufficiently reliable information about the applicability of the performed calculations. The presented model can be scaled, zoomed-in, rotated. Basing on the previews, we can determine if the input data contains major errors. Elimination of such errors should be performed before the final processing in graphical software.



Source: own study

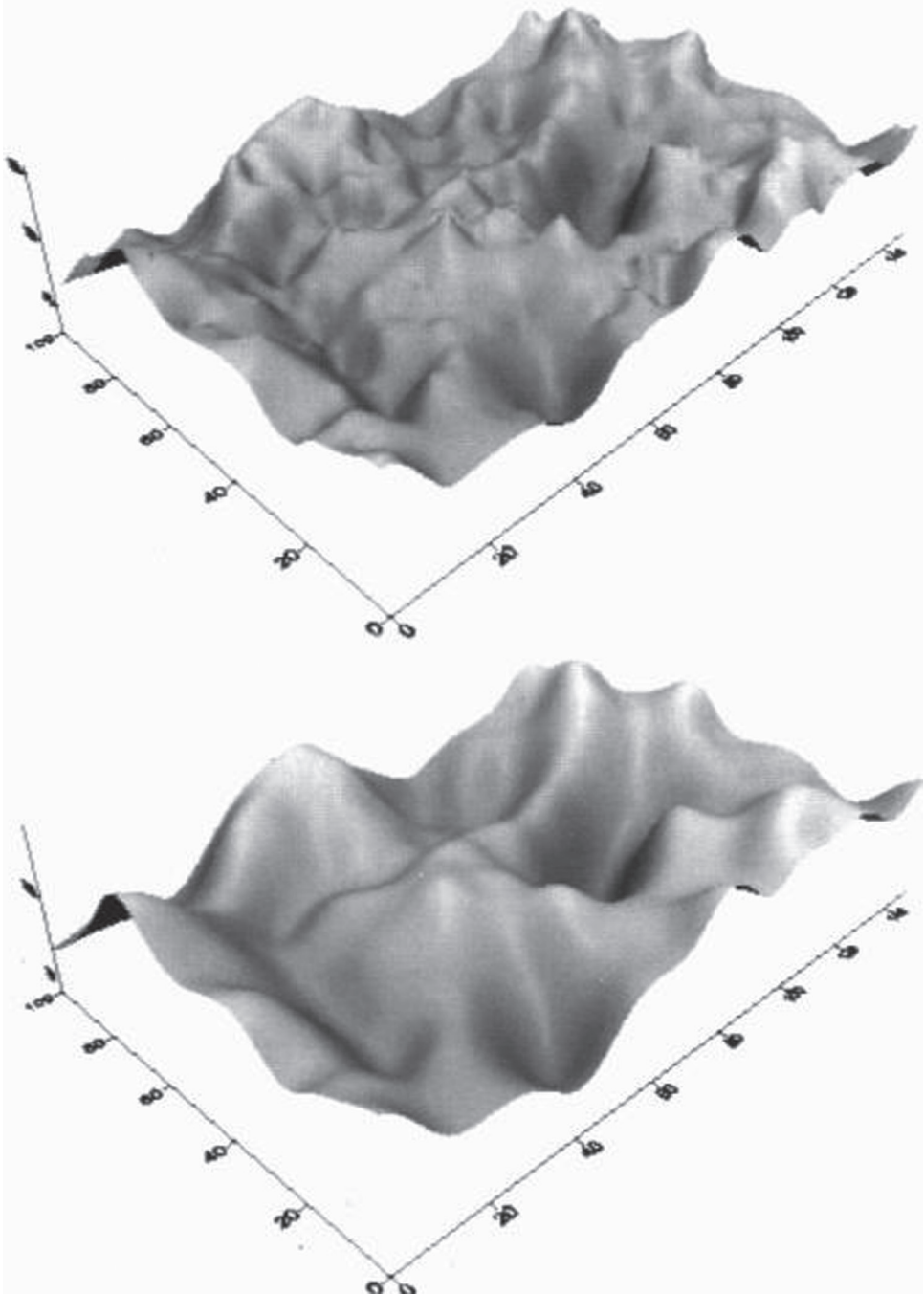
**Fig. 4.** A quick preview of a grid



Source: own study

**Fig. 5.** A quick preview of a grid with visible results of incorrect input data





Source: Galon 2009

**Fig. 6.** A map before and after smoothing



## 2.5. Modifying the GRID

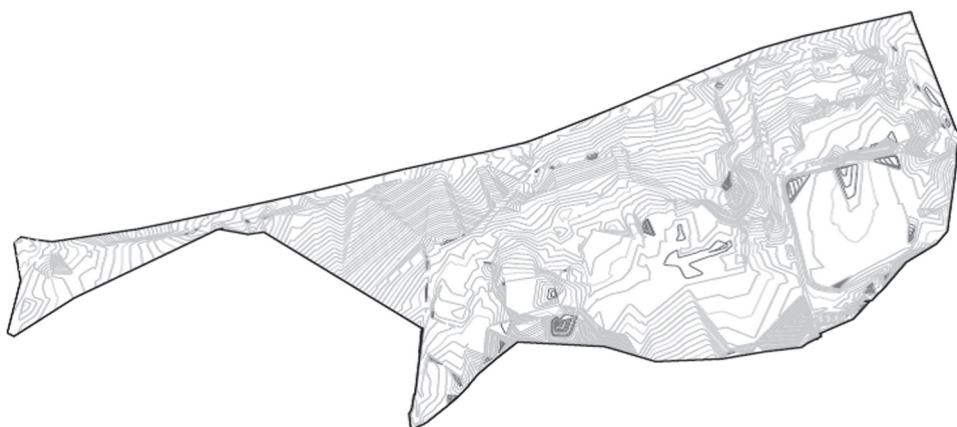
While using the program we can encounter a situation, in which the generated grid does not meet our expectations related to its later application for the purposes of landscape visualization. The SURFER software offers a way to correct it. It can be done using filters. The general rule of filtering is calculating the height of the analyzed node using the heights of the neighboring nodes. The process is based on algorithms which are most commonly used for image processing [Tadeusiewicz and Kohorda 1997]. We can choose from convolution filters:

- low-pass,
- high-pass,
- first order differential with edge detection,
- second order, calculated basing on *Gaussian* and *Laplacian*,
- gradient and other.

To obtain the required effect, the filter has to be averaging. The range of the analysis of neighboring nodes is selected in the program settings.

## 3. The results of using the SURFER software in a 3D visualization of the grange in Mściwojów

The described procedures were applied in practice during an international project: VITAL LANDSCAPES which is a part of the EU program CENTRAL EUROPE. One of the main goals of the project was to create a 3D visualization of a test object – a complex of historic ruins of the grange belonging to the Nostitz family in Mściwojów (Mściwojów commune, Jaworski district, Lower Silesia Voivodeship).

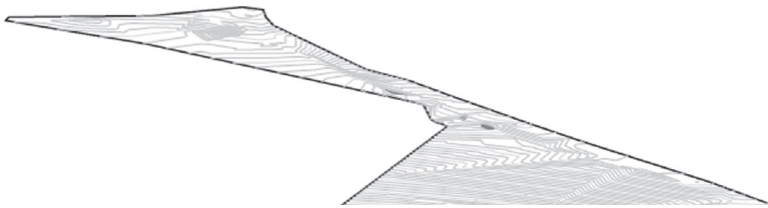


Source: own study

**Fig. 7.** A top view of the terrain model of the test object in an orthogonal projection

After creating the terrain model for the test object, it was noticed that it looked unnatural during manipulation in the 3D view. The reason for this is the concavity of the polygon defining the range of the study (see Figure 7) and the lack of continuation of similar surface outside of this area.

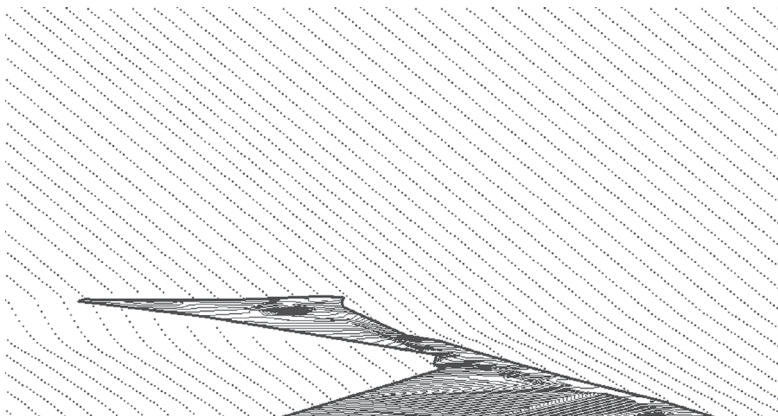
Supplementing the data around the area under discussion and using any geodetic method is time-consuming, and is not necessary for obtaining the satisfactory visual effect. For the purpose of visualization, the model of the object was placed in hypothetical surroundings. They were generated by densification of data using the GRID with the application of SURFER software. The Kriging algorithm was used with the default settings. The distance between nodes was set to 10 meters. Spreading the grid outside the visualized area, smoothed the image and removed the illusion of a chasm outside of its boundaries. These illusions are clearly visible while manipulating the object and observing it in 3D. This is the reason why the comparison of the effects of visualization was presented in an oblique projection (Figures 8 and 9). In this view, we can clearly see, that the generated grid adapts seamlessly to the boundaries of the model.



Source: own study

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**Fig. 8.** An oblique projection of a part of the model



Source: own study

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**Fig. 9.** An oblique projection of a part of the model of the extended area with the generated grid of points outside of the studied area

To obtain the best visual effect one should generate the grid of points in a wide area in such a way, that the effect of a far horizon is observable. As we get further from the modeled object, a flattening of the terrain model will happen. Applying a wide range of additional points will let us view the modeled objects conveniently from different perspectives, including those further away.

#### 4. Conclusions

The issue of landscape visualization is connected with the necessity of preparing data on large areas. As such data may be incomplete, we are forced to look for substitute solutions. The technology employing the SURFER software is sufficient for these purposes.

Preparation of the data is quick; moreover the data is verified. This applies to both input data and the final results: a terrain coverage grid. This technology can be freely used for such purposes.

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