"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.209
DOI: https://doi.org/10.3846/enviro.2017.209

Selection of Appropriate Scale of Relief Model

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Abstract. This paper presents the application of digital terrain model in developing a relief model. The digital terrain model served as the basis for the relief model. The research has taken into account the subject of combining different data in order to develop a numerical model of the land − surveying, bathymetry, maps. Another issue addressed was the one of vertical scale or exceeding it in the developed model. Its appropriate selection allows the correct representation of the terrain geomorphology. The paper presents research in carrying out relief model of Szczęśliwicki Park in Warsaw. The results show the link between the vertical scale or exceeding it and the accuracy (correctness) of relief model in large-scale descriptions. In addition, a verification of models was made with the use of a scanner that uses structural light.

Keywords: relief model, DTM, bottom model.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

Relief model is the subject of numerous research (Hurni 2008; Reed 1946). It would be replaced by the digital terrain models (DTM), which are easier and faster to do studies and updates. DTM is the basis for many GIS analyzes (Łubczonek, Zaniewicz 2012), for geomorphologist (Horowitz, Schultz 2014), for military (terrain analysis), hydrologist (Morris, Flavin 1994; Bogusz *et al.* 1999). In view of the increasing use of 3D printing problems relating to the development of releief models return.

A relief model is a model terrain's surface, it could be show the terrain or the bottom of river, rarely brought together these two models because of the different ways of data aqusition and different application. Relief model can be made on the basis of DTM. DTM is performed based on the following studies: tacheometric measurements, GPS, LIDAR (Slikas *et al.* 2014), topographic maps, base maps, and to the bottom model uses bathymetric measurements (Templin, Popielarczyk 2008). In our study, we combined together, these data, we assessed them and developed a comprehensive model of the area containing the model of the bottom of the water tank.

The aim of the study presented in this article is to present a selection of the vertical scale for relief model on a large scale for the terrain with elevation of 56 m.

Materials and method

Research related to the development of the relief model that shows the terrain and the bottom of the water tank. The problem in the implementation of such a model is a combination of data obtained from various sources and selection of the scale finished model.

Relief model can be developed based on digital terrain model. And it created based on various geodetic and cartographic. In our study, we analyzed the available materials for the area Szczęśliwicki Park in Warsaw (an area of 30 hectares and is located in the center of Warsaw).

Therefore, the development of the site concerned and the bottom of the water tank to model include a geodetic measurements and maps:

- Basic map scale of 1: 500 for the area of the park, a map drawn in the coordinate system PL-2000 (1).
- LIDAR data for the area of the park in the form of an ASCII file. Data files include LIDAR points, where the average density of the points was 1–4 points / m^2, which have been obtained with an error of average height included in the range of 0.2 m. On the other hand stitch the side of the net was 1 m. Elevation data used to complete the DTM prepared in PL-1992 and the height of refer to the PL-KRON86-NH (2).
- Measurement satellite (GPS). It was a measure of selected sections. The measurements were performed within one measurement day. Posted to the receiver and antenna Leica Viva (3)
- Data bathymetric Lake Szczęśliwicki of 2011, these data were obtained using sonar and a GPS receiver. The result of these measurements were isolines of height (4).

Further DTM developed based on the data. Due to the results of the above analysis to the development of NMT selected data from LIDAR and bathymetric data. Work began standardize the data in terms of coordinate systems.

LiDAR data were in the PL-1992, and bathymetric data in the PL-2000. Helmert transformation (conformal) was carried out. To get the height of the lake in a PL-KRON86-NH was adopted to replace the local system to system height "Zero Vistula" value corresponding to the height of the water in the system. Then go with the Zero Vistula system PL-KRON86-NH. The level of "Zero Vistula" corresponds to the value of 77.87 m the PL-KRON86-NH, which had to be added to the points system height "Zero Vistula".

Coordinates of points to perform digital terrain model prepared in the coordinate system PL-1992, and the height referred to the PL-KRON86-NH.

To develop the DTM assigned a regular grid of kriging. Kriging belongs to geostatistic of interpolation methods. This means that functions on the basis of stochastic, which takes into account the variability of random interpolated surface. The interpolation is done on a finding a statistical relationship between the values of known points in the data set, and the estimated value of the interpolated point.

The concept of elevation appeared much earlier than the same models plastic. Elevation p vertical scale model called the number expressing the ratio of the vertical scale 1 / M_v horizontal scale 1 / M_h Hence:

$$p = \frac{M_h}{M_v}, \tag{1}$$

where: p – elevation; M_h – horizontal scale, M_v – vertical scale.

p expresses the zooming vertical scale model. From (1) it follows p_{min}= 1 at equal M_h i M_v.

Selecting the vertical scale or elevation depends on several factors. The most important factor is the horizontal scale model. The choice of scale is also affected: the terrain, the system of forms geomorphological and their diversity and destination of relief model. So the model and its scale sets the first horizontal direction of research. It follows the basic conclusion. The number of factors that affect the value of the vertical scale of the map or the elevation increases with the decrease of the horizontal scale. The simplest ways of determining elevations are in the group of thematic maps (Table 1).

Table 1. The horizontal scale and elevation on thematic maps

Scale of thematic map	Elevation p
1: 20 000	2
1: 100 000	5
1: 150 000	9

For proper selection of the vertical scale and elevation it is necessary to investigate all the characteristic elements of the terrain (valley, canyons, craters). The above-mentioned forms may decide to vertical scale of the model. The Table 2 lists the most commonly used elevation for small-scale relief model depending on the terrain.

Table 2. Examples of horizontal scales and elevation for small-scale maps, models, depending on the type of terrain

Horizontal scale	Elevation			
	Lowland	Highland	Low mountains	High mountains
1: 1 000 000	4	4	3	2
1: 2 500 000	10	6	3	2
1: 5 000 000	10	6	4	2,5
1: 10 000 000	20	12	8	5

The described methods for determining the horizontal scale apply to small-scale maps at scales from 1:20 000 to 1: 1 000 000. or the majority of the proposed models, we are able to analyze the individual elements to choose the correct scale. The problem is the choice of scale for large-scale studies from 1: 500 to 1: 5000, which is conditioned more detail designed models. In these scales the output cut on maps can take up value of 0.5 m. This problem has been solved by the example of model plastic Szczęśliwicki Park. Initial horizontal scale M_h = 2000, and contour interval is 2.5 m or 5 m. The selection of a suitable elevation p, made four models in elevation p = 20, p = 10, p = 4 and p = 1. The reason for such large differences between the two scales was a large drop area on the area being developed. Implementation of four different models elevation require the selection of different values of contour interval, due to the use of same material for the construction of the positive pattern.

The next stage was to use the capabilities to perform contour model that represented the terrain by contour lines. Preparation of contour model was necessary to comply with the analog terrain model of Szczęśliwicki Park. Digital contour model has been divided into individual contours, which were then printed. All contours are marked by vertical and horizontal lines, in order to properly orient the contour of each other. The next stage was to cut contour (Table 3), which served as a template for cut contour in foam Austrotherm XPS (Fig. 1). Template was glued to the foam, and then using a knife bookbinding excised individual contours.

Table 3. The use of cut of contour

Elevation *p*	Contour interval
20	0,7 m
10	1m
4	3m
1	1m* print 3D

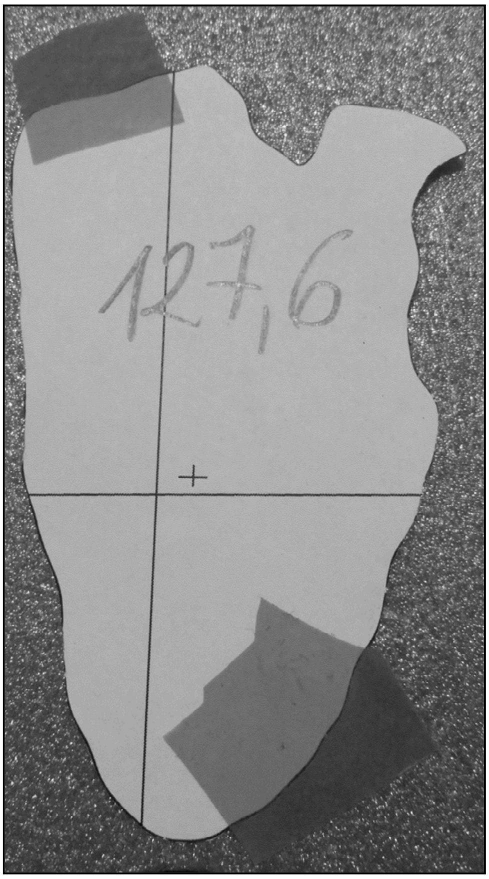

Fig. 1. A template for cut contour in foam (source: Ordon 2017)

Then you cut all the contours marked on each course lines. Then proceeded to glue model.

Research on the developed models can be divided into three main stages. The first was to verify the model in terms of detail. The second visual inspection of the correctness of selected clearance. The last and most important, a precision model was controlled by scanner uses structured light.

Results and discussion

For the analysis of studies was performed with individual four sections of the source materials (1)–(3). One of them was shown on the Fig. 2.

On the basis of cross-sections has been established that on the map there is an mapping error, because value obtained from the map differ significantly. The differences are formed in the range of 0.05 m to 3.2 m. The values obtained during the measurement and the GPS values from the LIDAR-u coincide. The differences are formed in the range of 0.01 m to 0.15 m.

Selecting the vertical scale or elevation for objects with a single form field does not cause problems. And if there are regions with varied terrain, should apply a variable scale for the different forms of terrain. This poses problems in small-scale studies and is often used. With multiscale studies seem to use a logarithmic scale when selecting vertical scales. With the appropriate choice of the value of the base of the logarithm, areas with large elevation are decrease with increasing height. In such cases, the model gives a uniform cartographic basis.

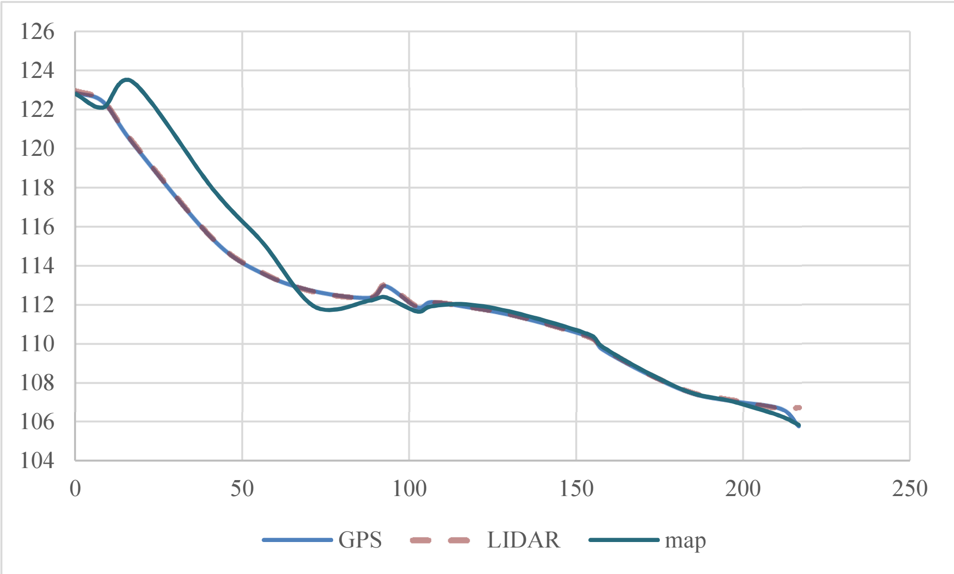

Fig. 2. The section of Lidar, GPS, maps data (source: own work)

Precision control using a scanner that uses light structural showed a link between the value of the vertical scale of the accuracy of the model (Table 4). The choice of scanning technology is dictated by its accuracies. Due to the small size of scanned objects, it is reasonable that the accuracy is not exceed ± 0.005 m. The following is a tabular summary of the test used a scanner.

Table 4. Accuracy analysis of the test field (source: Wrona 2014)

Distance range [m]:	
min	max
0,0030	0,4140
The values of the differences in distance to the individual scanners – control points	
min [m]	max [m]
0,0000	0,0033
Standard deviation	
min [m]	max [m]
0,0006	0,0028

The studies compared the scans of each model output data LiDAR. For the analysis was used 30 points distributed evenly over the made models and giving a clearly identifiable. Based on the difference coordinates X, Y, H, between the LIDAR data and scans each model calculated summary execution errors models (Table 5). The analysis was performed on the basis of the accuracy of the real errors and to calculate the average error used in the following formula (2):

$$m = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}}, \tag{2}$$

where: m – mean error; ε – resultant error; n – number of measurement.

$$\varepsilon = X - l, \tag{3}$$

where: X – resultant value (LiDAR); l – observation (spatial model).

Table 5. The results of the accuracy analysis (source: own work)

Elevation *p*	Mean error
20	±3,7 m
10	±4,1 m
4	±2,4 m
1	±1,9 m

Conclusions

An analysis of the source allowed the following conclusions:

The most reliable sources are direct measurements of GPS.

The analysis of finished models led to the conclusion that if you increase the contour interval, it the objects will be generalized and the accuracy of the model will be reduced. On the basis of visual inspection of the models tested, some irregularities were found in the elevation $p = 20$ and $p = 10$. Incorrect selection of the vertical scale has caused excessive pulling up. While the elevation $p = 1$ flattened the model, but it did not deprive it from readability. Elevation $p = 4$ allowed the most accurate presentation of geomorphology of the model.

The precision analysis results comparing the output of LiDAR and scanned relief models show the relationship between the value of elevation and the value of error in developing the model. Elevations with values 20 and 10 take similar values of the average error. Along with a reduction of the value, the error in developing the model reduces its values as well. For a full analysis it is necessary to develop and test the model with elevation equaling 1 using a stepped positive method. The results of the comparison made in the model printed in 3D, only allow to verify the technique.

For large-scale maps with elevation to 20 m normally the elevation $p = 1$ can be applied, but such studies are partially applicable. A selection of the variable scale reflecting changes in geomorphology can cause local distortion. It seems reasonable to provide a method for determining the elevation of the relief model in large-scale taking into account the known denivelation, the slope and shape of the slopes. This method could use a logarithmic scale. A selection of the appropriate base for logarithm, depending on the geomorphology of the area, will allow the correct representation of the terrain on the relief model.

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