3D MODELLING OF THE TERRITORY OF THE UKRAINIAN ANTARCTIC STATION "ACADEMICIAN VERNADSKY" BASED ON LARGE-SCALE TOPOGRAPHICAL RESEARCH

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Summary

A number of software products that provide the possibility of 3D modelling are analysed. As a result of the analysis, the advantages and disadvantages of each of those were identified and the optimum product for research implementation was selected. Also, a 3D model of the large-scale topographical map of the Ukrainian Antarctic station "Academician Vernadsky" was developed with the aid of Surfer software application.

Keywords

3D-model • 3D-modelling

1. Introduction

The purpose of the present work is to analyse and apply the existing software products for the creation of a 3D model of the territory of the Ukrainian Antarctic Station "Academician Vernadsky" on the basis of large-scale topographical plans. Representation of objects in three-dimensional format makes it feasible to expand their functional possibilities for their further application in different spheres and branches of science. That is, the creation of the 3D model of the Antarctic station "Academician Vernadsky" will allow the implementation of scientific developments and research into such specialised fields as: ornithology, zoology, glaciology, geology, oceanography, etc. Therefore, for the visual representation and determination of the location of research results, a topographical basis for data application purposes is fundamental.

In order to arrive at the end result discussed in this work, the following tasks had to be implemented:

- critical analysis of literary sources,
- analysis of theoretical and technological block diagrams for creating a three-dimensional model of a given territory,
- collating data concerning the territory of the Ukrainian Antarctic station "Academician Vernadsky" and carrying out their classification,

- constructing a three-dimensional model of the "Vernadsky" Antarctic station, with the structures that are located therein.

2. Unresolved parts of the general problem

Before the beginning of fundamental research, a critical analysis of literary and digital sources was conducted on the topic in question. Several unexplored problems were identified in this area, in order to optimise the goal of this type of research [Hlotov and Kolb 2006, Erwes et al. 2007]. It was indicated that there exists a small number of scientific publications and articles pertaining to the studied topics. At the same time, it has been shown that at present, during global climate change, especially in Antarctica, there exists a great need for research in the technical and economic field, in this particular area.

The input data for simulation was a large-scale topographical map of the territory of the Ukrainian Antarctic station "Academician Vernadsky" on the scale of 1:1000, in CAD format DXF/DWG.

3. Presenting main material

The first stage of the study was to determine the *a priori* estimation of the results of measurements, and the general analysis of the correctness of the input data (formula 1). The photogrammetric method relies on the fact that the removal of an object is from one point with the corresponding period. For the implementation of this method, phototeodolite kits can be used, in direct photogrammetric serif or camera only, provided that the reference points that will be used to orient the images will lie on the outside of the removable plot [Hlotov 2004, Hlotov and Marusazh 2013, Murat Yilmaza et al. 2018]. For taking off, steel points were used in the form of centres with forced centring of devices. In our case, the output data were as follows:

B = 15 m = 15 000 mm

Y = 150 m = 150 000 mm

m_b = 10 mm

f = 35 mm

$mp = mf = mz = mx$ = 10 mm

photo frame 22.2 × 14.8 mm

$$
\begin{aligned}
X_f &= \frac{B}{p} x_l \\
Y_f &= \frac{B}{p} f \\
Z_f &= \frac{B}{p} z_l
\end{aligned}
\qquad (1)
$$

where:

f – the focal distance of the DTC,
B – basis of shooting,
Y – distance to the subject of the shot,
x_l, z_l, p – the coordinates of the points on the left image and the longitudinal parallax,
$m_{X_\Phi}, m_{Y_\Phi}, m_{Z_\Phi}$ – mean square error coordinates X_f, Y_f, Z_f,
m_b – average square error of measurement of the basis of removal – 10 mm,
m_p, m_f, m_z, m_x – mean square error of measurement of the coordinates of the image, parallax and focal length.

The formulas mentioned above differ depending on the value adopted by the variables (formula 2). In order to determine the mean square error, we will use a replacement:

$$p = \frac{Bf}{Y},$$

thus:

$$dX_f = \frac{x_l Y}{Bf} dB + \frac{Y}{f} dx_l - \frac{x_l Y^2}{Bf^2} dp$$

$$dY_f = \frac{Y}{B} dB + \frac{Y}{f} df - \frac{Y^2}{Bf} dp \qquad (2)$$

$$dZ_f = \frac{z_l Y}{Bf} dB + \frac{Y}{f} dz_l - \frac{z_l Y^2}{Bf^2} dp$$

transition to mean square error

$$m_{X_f} = \sqrt{\left(\frac{x_l Y}{Bf}\right)^2 m_B^2 + \left(\frac{Y}{f}\right)^2 m_{x_l}^2 + \left(\frac{x_l Y^2}{Bf^2}\right)^2 m_p^2}$$

$$m_{Y_f} = \sqrt{\left(\frac{Y}{B}\right)^2 m_B^2 + \left(\frac{Y}{f}\right)^2 m_f^2 + \left(\frac{Y^2}{Bf}\right)^2 m_p^2} \qquad (3)$$

$$m_{Z_f} = \sqrt{\left(\frac{z_l Y}{Bf}\right)^2 m_B^2 + \left(\frac{Y}{f}\right)^2 m_{z_l}^2 + \left(\frac{z_l Y^2}{Bf^2}\right)^2 m_p^2}$$

$$m_{X_f} = 0.07\text{M}$$
$$m_{Y_f} = 0.23\text{M}$$
$$m_{Z_f} = 0.05\text{M}$$

Having analysed the value of the a priori assessment of accuracy, we can conclude that the available accuracy of the measure meets the requirements of the instructions for drawing up large-scale plans; namely, the accuracy of determining the coordinate Y, in this case of height $m_{Y_\Phi} = 0{,}23_M < m_Y = \frac{1}{3}h = 0.33_M$. The mean square error for the determination of the plan coordinates is $m_x = m_x = 0.1_M$, therefore, in this case it remains within the tolerance range and is equal to $m_{x_\Phi} = 0.07_M$, $m_{z_\Phi} = 0.05$ [Zamirroshan 2004, Mazaheri and Momeni 2008, Tretjak et al. 2013].

Subsequently, for the construction of a three-dimensional relief model, the functionality of such programs was analysed: AutoCAD, ArcGIS, Surfer and Digitals [Alidoost and Arefi 2015, Hosseininaveh et al. 2015, Agrafiotia et al. 2017, Emamgholian et al. 2017].

In the framework of the three-dimensional model of the study area, input data were topographic surveys made using various measuring techniques over many years. The main theoretical works were also analysed, namely:

- data processing algorithms,
- common technologies,
- basic software used in this type of research,
- basic functional dependences [Tilly et al. 2016].

In order to achieve this goal, we chose the Surfer software application [Burshtins'ka et al. 2003, Hoegner et al. 2018]. To get started, a catalogue of three-dimensional coordinates in the Excel package, which was measured by the GPS method, was generated (Fig. 1).

Source: Authors' own study

**Fig. 1.** Catalogue of three-dimensional coordinates

In the Surfer software application, we produced a regular grid surface model. For this purpose, in the Data tab, we chose the previously created coordinate directory. The next step was to configure the Grid settings (Fig. 2).
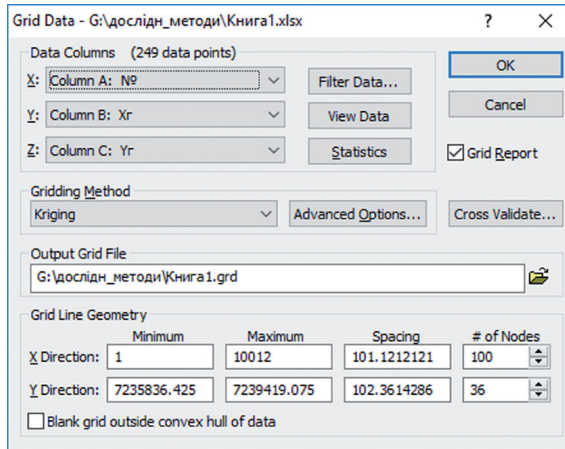
Source: Authors' own study

**Fig. 2.** Parameters of the grid to be created

In the next step, the software created Grid file, and automatically generated a report about errors and accuracy of its construction (Fig. 3).
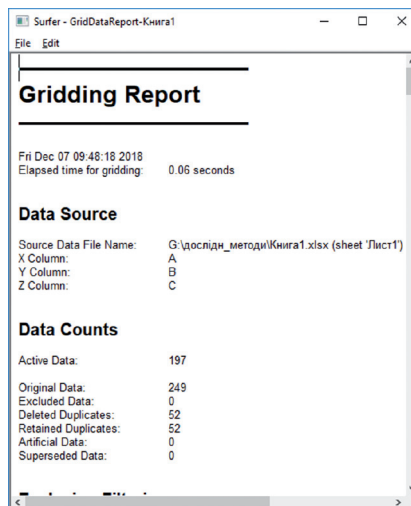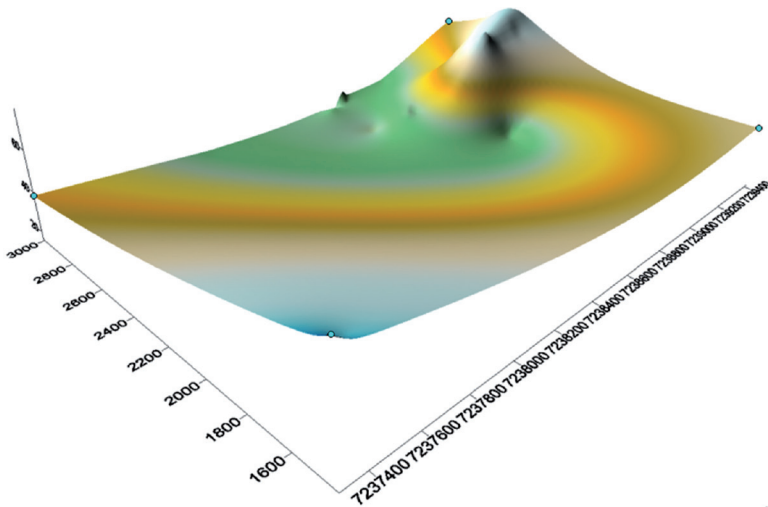

Source: Authors' own study

Fig. 3. Gridding Report

Next, a map of the horizontal lines was constructed using the points measured by the GPS method. The software chooses the New Contour Map function as the data used by the directory of three-dimensional coordinates (Fig. 4).
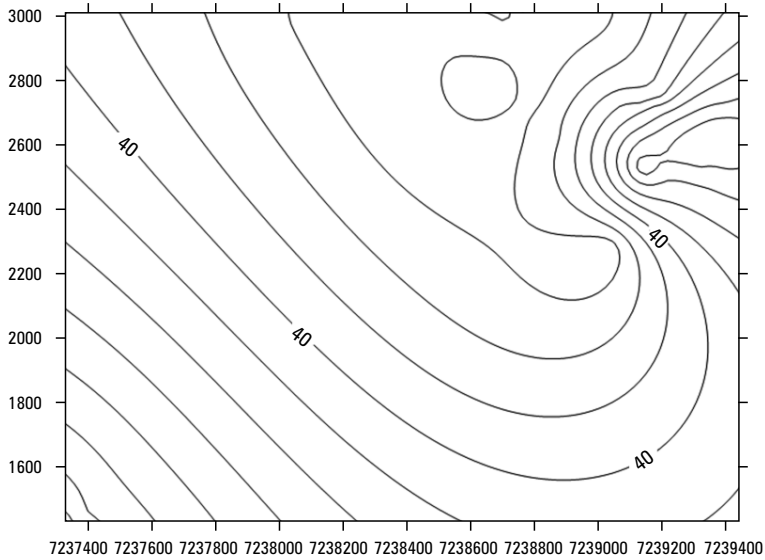
Source: Authors' own study

Fig. 4. Map of the Galindez Islands

Source: Authors' own study

Fig. 5. Three-dimensional relief model of the Ukrainian Antarctic station "Academician Vernadsky"

To construct a three-dimensional map, the new 3D Surface function was used in the software application. The final result of the work is the presentation of the general 3D model of the Ukrainian Antarctic station "Academician Vernadsky" (Fig. 5).

4. Conclusions

During the course of the work, a 3D model of a large-scale topographical plan for the region of the Ukrainian Antarctic station "Academician Vernadsky" was created. An analysis and comparison of the processing of input data in the Surfer and Digitals software applications was also conducted. The result showed that Surfer is the optimal software application for creating a three-dimensional model, since when working in Digitals software, the data were displayed incorrectly, and some were totally absent, which prevented further processing of materials and reaching the ultimate goal.

The prospect of further research is to refine and complement the 3D model, namely: the analysis of *a posteriori* assessment of accuracy, the exclusion of incorrect data, the creation of three-dimensional models of structures, as well as graphic representation of the types of structures (textures, forms).

It is also possible to convert and edit incoming data for further processing in other software products. This step will extend the range of operations and functions that can be used to improve the visualization and further processing of the qualitative and quantitative characteristics of objects, which will increase the information content of the created product.

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