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Comparison of Elevation Data of the Czech Republic for Designing Military Constructions

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Abstract:

Current elevation database of the Czech Republic territory is obsolete and unusable for designing constructions. The paper deals with utilization of new elevation data of the airborne laser scanning for the designing of military buildings. The newly prepared digital elevation database will be the result of the airborne laser scanning of the Czech Republic (2009-2012). This paper compares the current elevation data (digital terrain model of 3rd generation) and new altimetric data (digital terrain model of 4th and 5th generations) with a geodetic measurement in situ.

Keywords:

Elevation data, designing, digital terrain model, military construction.

1. Introduction

The development of modern information technology has a great influence on the way of constructions design. The modern trend is to design directly in 3D space, if it is possible to use the technology of the Building Information Modelling (BIM design method is useful especially for the design of buildings) or a dynamic model of terrain (designing earthworks and road constructions) [1].

High quality elevation data are the basis for designing in 3D space. Current elevation data of the Czech Republic territory are obsolete and inoperable. It is obvious, that it is necessary to create a new digital elevation database, which should meet the needs and requirements of both the Czech Government and the Armed Forces. Nowadays the Airborne Laser Scanning of the Czech Republic is in process. Data of this process will be a source for the creation of the new digital elevation database. This data will be more accurate and it will offer the wide range of utilization in various spheres.

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In this paper, the current elevation data (digital terrain model of 3rd generation) and new elevation data (digital terrain model of 4th and 5th generations) are compared with geodetic measurement in situ. It was rather complicated to choose a suitable area of research where geodetic measurement and data from airborne laser scanning are available. Eventually part of the military training area in Bechyně was selected as the area of research. There was made a geodetic measurement in 2009, which served as the basis for the designing of the National polygon C-IED (Counter – Improvised Explosive Devices) in Bechyně. The airborne laser scanning of this place was realized in 2010 just before the start of construction work on the National Polygon C-IED.

2. Geodetic Data

All these data were provided by the Military Geographic and Hydro-meteorological Office in Dobruška. These geodetic data are determined especially for the Czech Army, so they are processed in the Universal Transverse Mercator (UTM) projection system, in the World Geodetic Coordinate System (WGS 84).

2.1. Digital Terrain Model from Geodetic Measurement

This model was obtained using geodetic measurement in situ. Basic control points were measured by polar method in the 4th accuracy class. Fig. 1 shows geodetic measurement in a Triangulated Irregular Network – TIN form (a grey rectangle delimits the area of research – 680 × 420 metres).

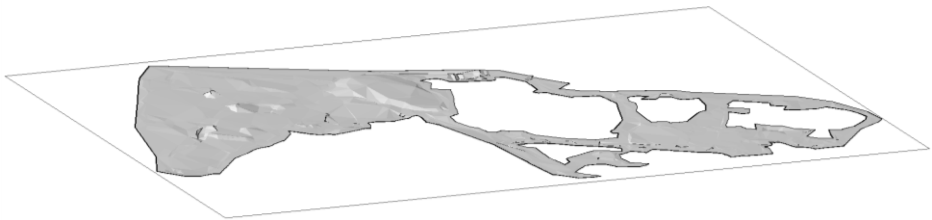

Fig. 1 Digital terrain model from geodetic measurement

2.2. Digital Terrain Model of 3rd Generation (DTM 3)

The Ministry of Defence of the Czech Republic created this model using stereo photogrammetry in 2003 – 2008. It has a mean square error of an elevation 1 – 2 metres in the open areas, 1 – 2 metres in the urban zones and 3 – 7 metres in the forest. DTM 3 is provided in the TIN form by segment 10 × 10 kilometres (Fig. 2). Altitudes of the terrain are determined for nodal points of network 20 × 20 metres.

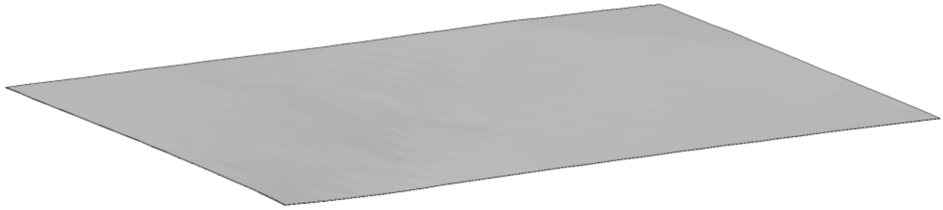

Fig. 2 Digital terrain model of 3rd generation (size of the area is 680 × 420 metres)

2.3. Digital Terrain Model of 4th and 5th Generations (DTM 4 and DTM 5)

DTM 4 and DTM 5 come from Airborne Laser Scanning of the Czech Republic. Airborne Laser Scanning uses the method of Light Detection and Ranging (LIDAR). LIDAR for terrain and land surveying has made significant contributions to many environmental, engineering and civil applications and it has been used increasingly by the public and commercial sectors since the early 1990s [2]. An airborne LIDAR data acquisition system estimates the distance between the instrument and a point on the surface by measuring the time the laser pulse needs to return. Differential Global Positioning System (DGPS) and Inertial Navigation System (INS) complement the data with position and orientation, respectively. The laser’s capability to penetrate gaps in vegetation allows measuring occluded ground, as at least first echo (FE) and last echo (LE) can be recorded. Hence, LIDAR is superior to traditional photogrammetric techniques such as stereo matching [3]. Furthermore, as LIDAR is an active sensor, it is independent from external light conditions, and is therefore not affected by shadows and can be used at night [4].

DTM 4 (Fig. 3) is provided in the GRID form (5×5 metres) with a mean square error of an elevation of 0.3 metre in the open areas and 1 metre in the forest. The whole model of the Czech Republic will be created within six months after scanning in 2012 [5].

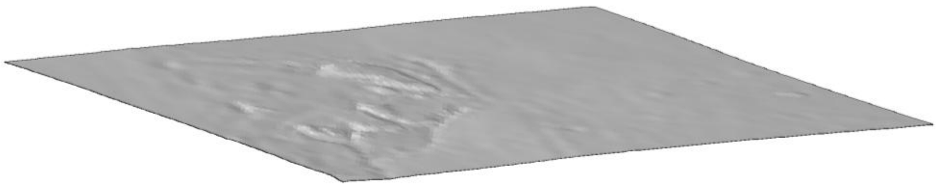

Fig. 3 Digital terrain model of 4th generation (size of the area is 680 $\times$ 420 metres)

DTM 5 (Fig. 4) is provided in the TIN form with a mean square error of an elevation of 0.18 metre in the open areas and 0.3 metre in the forest. The whole model of the Czech Republic will be created within two years after scanning in 2015 [6].

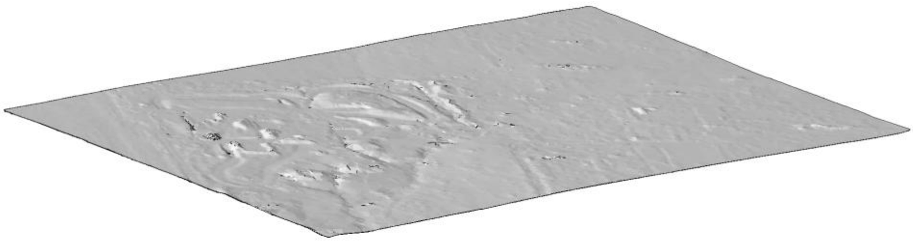

Fig. 4 Digital terrain model of 5th generation (size of the area is 680x420 metres)

3. Evaluation Criteria

Four temporary roads were designed in the area of research and the routes of these roads are displayed in Fig. 5. The same four roads were projected on four various digital terrain models. There were calculated volumes of excavations and embankments. DTMs were compared on the basis of total volume of earthworks.

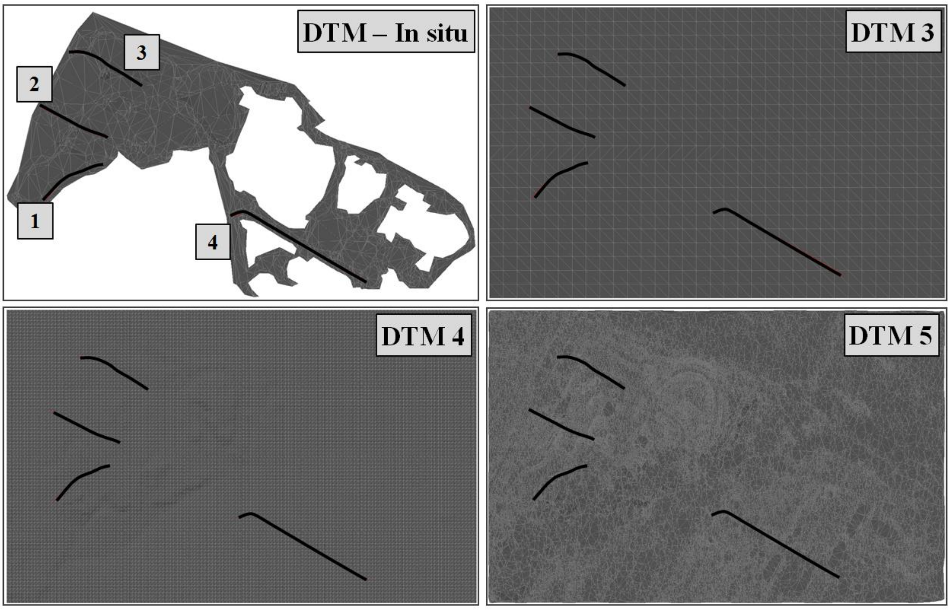

Fig. 5 Routes of temporary roads

The designed parameters of the temporary roads are as follows: the width of the road is 7.2 m, the structural height of the road is 0.45 m, the tilting of the road was done around the axis, with a minimum radius of the circular arch 100 m and a total length of the roads 800 m. The elevation profiles of two temporary roads were designed with a convex curve and the other roads were designed with a concave curve. On the tops or in the valleys of the apex angles were designed levelling curves with a radius of 1000 m. Drainage of the temporary roads was designed as a triangular ditch with minimum depth of 0.2 m below an outfall of a plain.

4. Data Processing

The whole design of four temporary roads was created by Autodesk's software AutoCAD Civil 3D. AutoCAD Civil 3D software is Autodesk's building information modelling solution for civil engineering. AutoCAD Civil 3D produces a single model, with intelligent and dynamic data, enabling designers to more quickly make a design change at any stage of the process. The model automatically reflects any changes to drafting and annotation throughout the project. The software enables designers to more quickly process earth volumes between existing and proposed surfaces [7]. This sophisticated software offers various functions. Only some of them have been used, especially Generation DTMs from survey data and corridor modelling, which combines horizontal and vertical geometry with flexible cross sectional components to create a parametrically defined dynamic 3D model of the roads.

All DTMs were created by the same method from the text file (encoding ASCII), which contained *x*-, *y*-coordinates and altitudes of points. Initially, these points were imported into AutoCAD Civil 3D program and there were created DTMs, which were displayed by TIN. Next the direction, the vertical alignment and the sample crosssections of the roads were designed. AutoCAD Civil 3D generated automatically the road corridors (Fig. 6) and eventually the table of earthworks volumes was made.

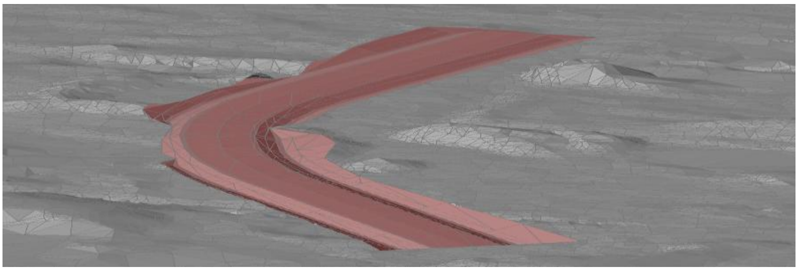

Fig. 6 Design of road corridor – route no. 1

5. Results

Particular DTMs were compared according to the volumes of embankments and excavations of four temporary roads (Tables 1 and 2). The tables show differences of earthworks quantity among individual DTMs.

DTM 3 is entirely unsuitable for designing military constructions. The total value of excavation of DTM 3 was more than three times larger than the total value of excavation of DTM in situ. According to the values in the tables, DTM 3 is exploitable neither for designing military constructions, nor for construction planning.

The difference between DTM in situ and DTM 4 and DTM 5 oscillates between 1 and 10 per cent. Even though the aggregate volumes of earthworks (DTM 4 and DTM 5) are very similar, the results confirm minor discrepancy between them. This discrepancy is connected with the declared total mean error of an elevation and the form of DTMs. DTM 5 (TIN form) represents the real terrain much better than DTM 4 (GRID form).

These results are relatively interesting and they show a considerable increase in the accuracy of data surveying compared to DTM 3. On the other hand, there were compared merely the data from one locality, so it is important to accomplish much more comparisons in other localities. Unfortunately, as mentioned before, it is really difficult to find a suitable area of research where an actual geodetic measurement, DTM 4 and DTM 5 are at disposal.

Tab. 1 Volumes of earthworks by roads

Type of surface	Road 1		Road 2		Road 3		Road 4	
	Embankment [m^3]	Excavation [m^3]	Embankment [m^3]	Excavation [m^3]	Embankment [m^3]	Excavation [m^3]	Embankment [m^3]	Excavation [m^3]
DTM In situ	222.9	1 411.5	256.3	340.1	162.8	578.3	2 051.7	3 674.2
DTM 3	41 160.0	4 318.6	0.0	2 273.0	0.0	4 019.8	2 501.0	6 047.5
DTM 4	181.4	1 395.5	257.7	314.6	146.2	713.8	1935.7	4 196.5
DTM 5	197.5	1 287.0	316.1	474.4	165.5	607.1	1991.1	4 031.5

Tab. 2 Total volumes of earthworks

Type of surface	Totally		Totally	
	Embankment [m^3]	Excavation [m^3]	Embankment [%]	Excavation [%]
DTM In situ	2 693.7	6 004.1	100	100
DTM 3	2 509.9	16 658.9	93	277
DTM 4	2 521.0	6 620.4	94	110
DTM 5	2 670.2	6 400.0	99	106

Despite the fact that the new elevation data (DTM 4 and DTM 5) will be much more precise than the older elevation data (for instance DTM 3), they will still not be probably usable directly for the final designing of military constructions. Earthworks constitute one third of aggregate cost of the whole project, so that the calculation of earthworks has to be as accurate as possible. Designers must have a geodetic measurement at disposal straight from the area of interest; otherwise it can lead to a waste of money.

6. Conclusion

The project of the temporary roads was chosen, because it can be a typical task of engineers. The Czech Republic territory was affected by floods many times in the last years. Engineers quite often have to solve projects of temporary roads, which were damaged during floods.

As stated above, a geodetic measurement directly done in the area of interest is still the main source for creating DTM and subsequent designing. On the other hand, there are many other phases of designing, when these data could be exploitable. Sometimes it is necessary to estimate very quickly a calculation of earthworks, which constitute a significant part of the project. This task is very common especially during designing temporary roads or bridges after floods. Modern software offers a very simple comparison between DTMs before and after flood. Using modern software, the designers are able to estimate the volume of earthworks more quickly. They can assess bank's condition and avoid possible dangers before building. Moreover, DTM 4 or DTM 5 could be beneficial during construction planning, designers are able to get very credible preliminary project without geodetic measurement in situ. It is obvious that these data can help to solve numerous problems even before the designing of constructions.

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