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COMPARISON OF THE PUBLICLY AVAILABLE DIGITAL TERRAIN MODEL PROVIDED BY THE HEAD OFFICE OF GEODESY AND CARTOGRAPHY WITH GNSS SATELLITE MEASUREMENT

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Summary

Due to the ever-better accessibility of the digital terrain model (DTM), it is enjoying growing popularity as a source of information about the surrounding world. It became even more approachable when DTM data covering the whole of Poland was made available free of charge on the Geoportal website. The GRID with a resolution of 1 meter per 1 meter covers virtually the entire country. The data on the Geoportal does not only refer to the measurements processed into a grid of squares, but also includes measurement data. They can be accessed through a systematic division into section sheets in the 1992 system. The paper presents research on assessing the accuracy of these publicly available data, compared to measurements obtained with the GNSS observations. The analysis involved data directly from the measurement device, not yet processed into a grid of squares. As part of the research, the height of 3 objects was compared. It was decided to measure the terrain profiles. To get as close as possible to the source data provided at the Geoportal website, the selected points of profiles previously identified in the point cloud were measured. This approach freed the final results from the need for height interpolation for the data selected for analysis. As result, the potential source of errors in such an approach was eliminated. Although during a classical profile measurement with this technology the selection of points would certainly be different, for research purposes this approach seems optimal. For this reason, in addition to the expected deviations resulting from the height differences of the tested points, deviations from the data from the point cloud of the XY coordinates, related to the adopted technology, are also presented.

Keywords

digital terrain model (DTM) • point cloud • DTM error • GNSS

1. Introduction

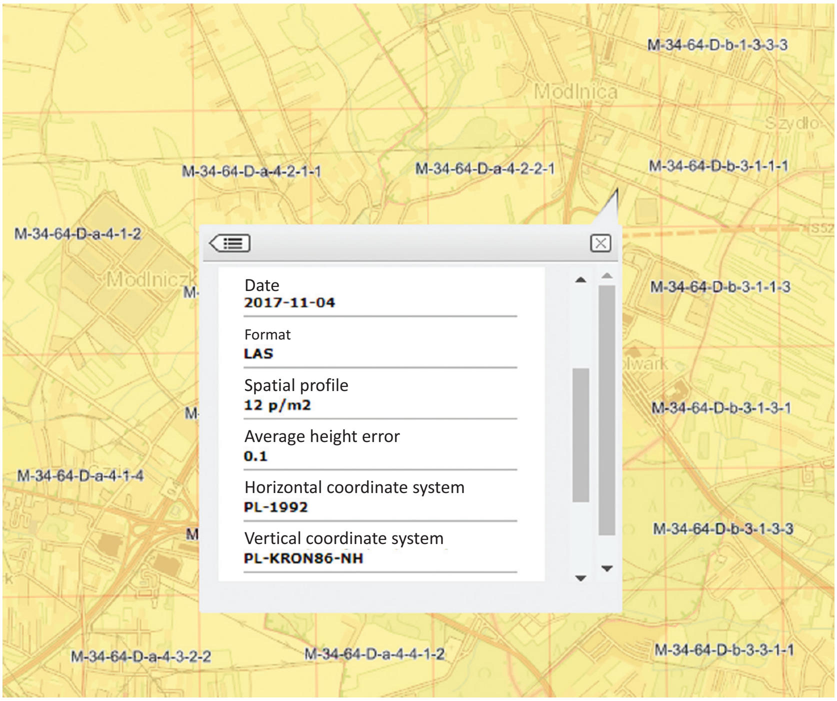
Methods of measuring terrain details are being developed along with technological progress. This applies not only to hardware capabilities, but also to the possibility of data publishing and their spatial analysis [ICA 2016]. Laser scanning becomes less a technology limited only to companies with specialized hardware, software and qualified staff. Thanks to the government website geoportal.gov.pl, where data from laser scanning of the entire country is publicly accessible, virtually anyone can use them. The only condition is to have dedicated software and hardware. This is in line with the tendency to develop modern methods in the process of generating DTM. [Borkowski et al. 2006, Hejmanowska and Warchoł 2010, Milinković et al. 2014, Pająk et al. 2011, Pyka et al. 2012]. A question arises whether the accuracy that is declared by the contractor corresponds to reality. This question is justified, especially in the aspect of other data published for the territory of the country – a grid with a size of 100 meters per 100 meters available for individual Polish voivodeships. 'For NMT100 in the range of 111 points, the height deviation increases evenly from 0 to 4 m. For the remaining 53 points, the increase in deviation is more rapid and quite large – from 4 up to 17 m' [Jarończyk 2015]. The errors contained therein reached up to a dozen or so metres, which made them illustrative data rather than data meeting the accuracy conditions for the purposes of surveying. They could only be used after verification and rejection of gross errors. Due to the key accuracy parameter as an element directly affecting the quality of products created on the basis of DTM [Stateczny i Łubczonek 2004, Gościewski 2005, 2007, 2014, Paszotta i Szumiło 2006, Gołuch et al. 2008, Wyczałek 2009, Gumus i Sen 2013, Suchocki et al. 2013, Glowienka et al. 2017], research works were undertaken.

The GNSS technology was chosen for the purposes of research and comparative analysis.

According to the authors, the accuracy guaranteed by this technology is sufficient. Measurement by other methods (e.g. levelling, tachymetry) would give a more accurate result, however, the GNSS technology was adopted for research works due to its universality and accuracy. Issues related to the accuracy and comparison of GNSS methods with other measurement methods for creating DTM are widely described in scientific publications [e.g. Suchocki et al. 2013, Uradziński and Doskocz 2015].

2. Digital Terrain Model (DTM)

The Digital Terrain Model is a numerical representation of the terrain surface, usually created by a set of adequately selected points (x, y, z) of this surface and interpolation algorithms enabling the reconstruction of its shape in a specific area [Gaździcki 1990]. As to the topic of this paper, the most significant part of the definition refers to the selection of x, y, z points. In order for the results to meet the objectives of the research work, the control heights were obtained in a way that eliminated the need to use an interpolation algorithm. For the study areas, data were obtained from the geoportal.gov.pl website. The average height error is 0.1 meter, density 12 p/m^2, horizontal coordinate system 1992, vertical coordinate system PL-KRON86-NH. Sheets grouped in the 1992 sectional arrangement at a scale of 1:1250 (Fig. 1).



Source: geoportal.gov.pl

Fig. 1. DTM data download window

3. Research area

For research purposes, three essentially different objects were selected:

- a fragment of an asphalt roadway located at Studzienka Street in Modlnica in the Wielka Wieś municipality,
- a grassy area with a much greater altitude differentiation located near the Krakus Mound in Kraków,
- an area covered with lush vegetation, plot no. 988 at Stelmachów Street in Kraków (Fig. 2).

The selection of objects for the study was based on the assumption of maximally varied surface as possible, which is important for measurements made with the laser scanning technique (Fig. 3).

Source: Authors' own study based on GoogleMaps

Fig. 2. Location of research objects

Photo: M. Zygmunt, W. Boduszek

Fig. 3. Research object at Studzienka Street (left), the Krakus Mound, Stelmachów Street (right)

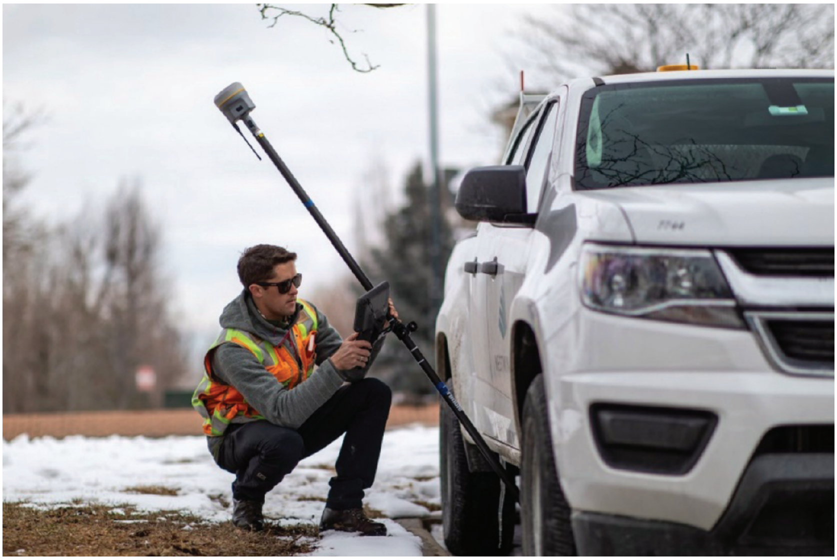
4. Measurement methods

All measurements were carried out in spring 2021. The equipment used was the satellite receiver Trimble R12i (Fig. 4, 5) with a very high measurement precision. The advantages of this device are:

- a real-time inertial navigation system (INS) that detects and corrects deviations in IMU readings caused by usage, helping to ensure the quality and integrity of measurements over the entire measurement period,
- equipped with a 672-channel board that tracks not only GNSS signals, but also satellite RTX corrections. In addition, by offering the xFill function, i.e. to use RTX service in case of loss of connection to the reference station, providing access to corrections at the level of accuracy of RTK/RTN measurement worldwide, via satellite or the Internet,
- cooperation with platforms such as Android or iOS,
- high strength (protection class IP-67),
- the device can simultaneously track the signals of various satellites, including: GPS, GLONASS, SBAS, Galileo, BeiDou, QZSS.
- it is also equipped with a DSP processor that allows detection of false GNSS signals and the recovery of performance.

Photo: M. Zygmunt, W. Boduszek

Fig. 4. Receiver and controller R12i



Source: https://geotronics.com.pl

Fig. 5. Measurement using IMU technology

The equipment is powered by a 7.4V 3.7 Ah battery that allows for all-day operation.

According to the manufacturer, the positioning accuracy in static measurement at high precision guarantees the accuracy at the level of 3 mm, while vertically up to 3.5 mm. When using RTN measurement, where a single base station is up to 30 km away, it predicts an error of up to 8 mm horizontally and 15 mm for height.

The measurements were taken in good weather, with a cloudless sky. The air temperature was 24 degrees Celsius.

Each point delineation was followed by a measurement, which was preceded by an increase in the length of measurement to a period of one minute. This was to determine the most accurate position of the receiver. The measurement and delineation process was carried out using the IMU function, trying to keep the device as little deviated from the vertical as possible. The process was performed for each of the points with obtaining the FIXED precision.

Such activities were performed for 3 research objects.

5. Research area

5.1. Modlnica, Studzienka Street

The profile was measured in the area of the municipal road plot (Fig. 6). It serves as an access road to nearby firms. The measurement included 20 points selected based on data obtained from a file in LAZ format. The profile length is 17.54 m. The entire study was made in the flat coordinate system 1992, elevation system – Kronsztadt-86.

Source: Authors' own study based on GoogleMaps

Fig. 6. Profile location (A5-B5) in Modlnica at Studzienka Street against an orthophotomap

5.2. Kraków, Krakus Mound

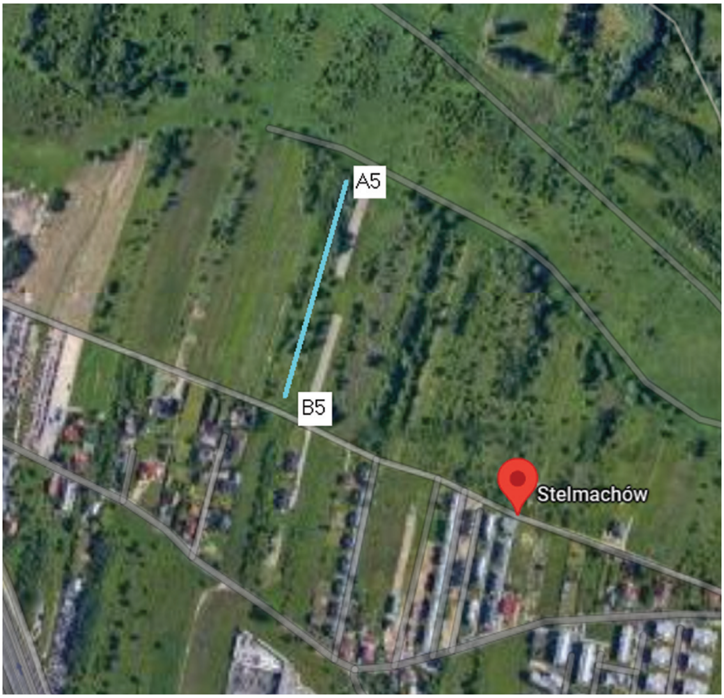
Due to small differences in height on the remaining objects, it was decided to choose one object with a more varied landform. The vicinity of the Krakus Mound was used as a research object. A terrain profile was made over a distance of 68 meters, with an average distance between points of about 1 meter. Reference system 1992, elevation system – Kronsztadt-86 (Fig. 7).

Source: Authors' own study based on GoogleMaps

Fig. 7. Profile location (A2–B2) in Kraków, Krakus Mound against the orthophotomap

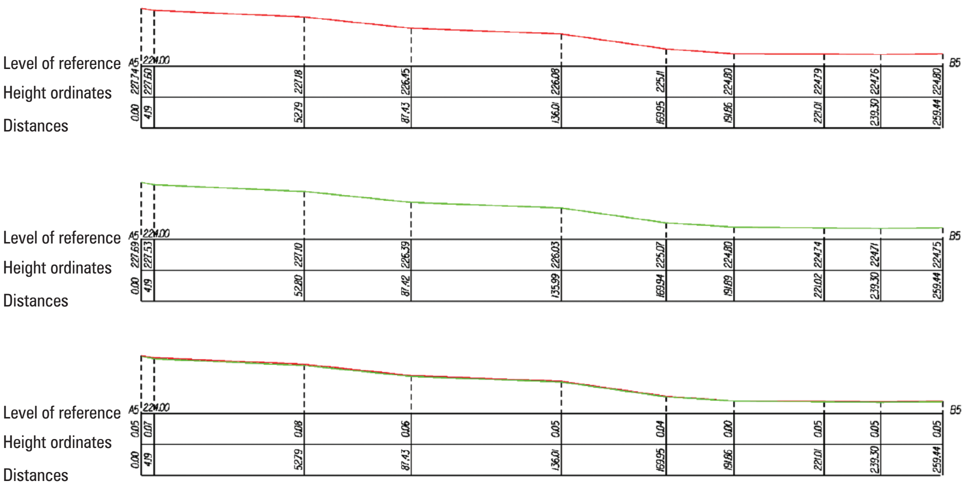
5.3. Kraków, Stelmachów Street

The profile was based on 10 points located on the 988 plot at Stelmachów Street. Points have been distributed mainly in terms of their availability. The area is characterised by high vegetation cover. In this case, all calculations were made in the flat coordinate system 2000/7, elevation system – Kronsztadt-86 (Fig. 8). Profile drawings were also provided. The data come from DTM, GNSS measurement, and a third profile – differential (Fig. 9).



Source: Authors' own study based on GoogleMaps

Fig. 8. Profile location (A5–B5) in Kraków, Stelmachów Street against the orthophotomap



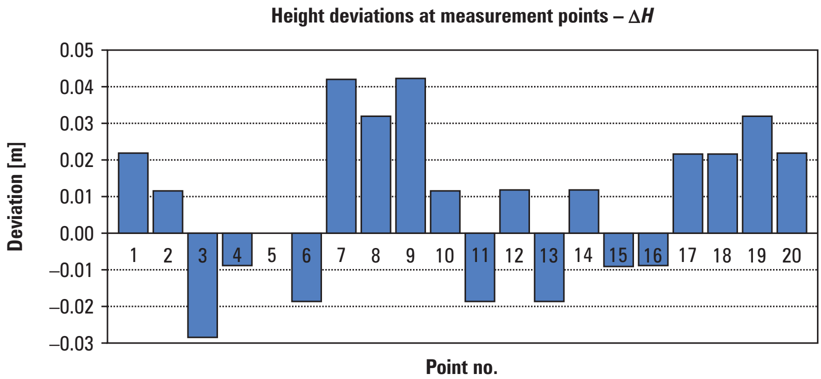
Source: Authors' own study

Fig. 9. Illustrative profile lines A5-B5 (red – DTM data, green – GNSS measurement) with a differential profile

6. Results overview

6.1. Modlnica object, Studzienka Street

According to the analysis of the results, situational delineation was carried out with adequate accuracy. This is evidenced by the maximum linear deviation ΔL = 0.03 m. The obtained height differences indicate the preservation of accuracy compared to DTM (Fig. 10). The information provided on the GUGiK website shows that the average error of the points for height is 0.1 meter.

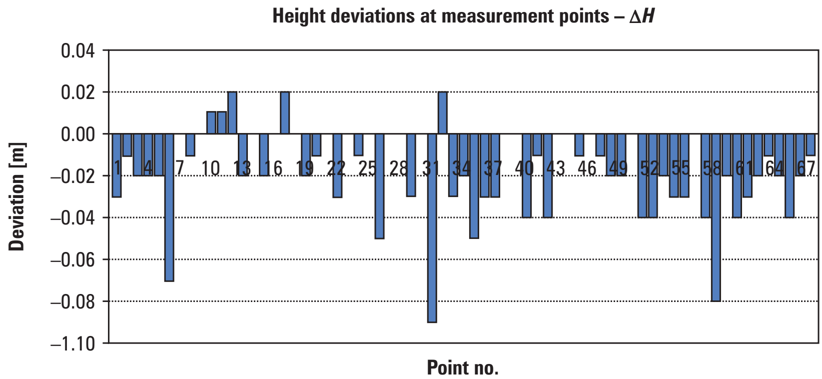


Source: Authors' own study

Fig. 10. Deviations in height ΔH for the Modlnica object

6.2. Kraków object, Krakus Mound

The results are approximate to those expected. No observation differed from the accuracy of the DTM data declared by the provider (the maximum is 9 cm – Fig. 11). The method of locating *XY* profile points on the basis of DTM also raises no objections. The maximum linear deviation is 0.06 meters.

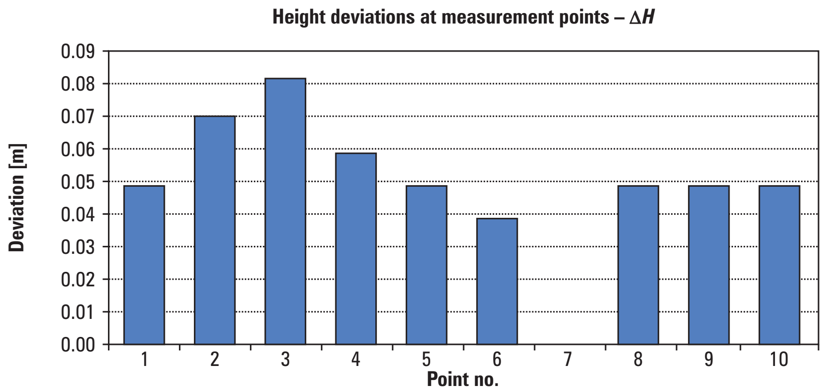


Source: Authors' own study

Fig. 11. Deviations in height ΔH for Krakus Mound

6.3. Kraków object, Stelmachów Street

In this case, there is a clear trend in height deviations indicating a rich vegetation cover. However, even this measurement was not affected by an observation that deviated from the accuracy declared by the DTM data provider (Fig. 12).

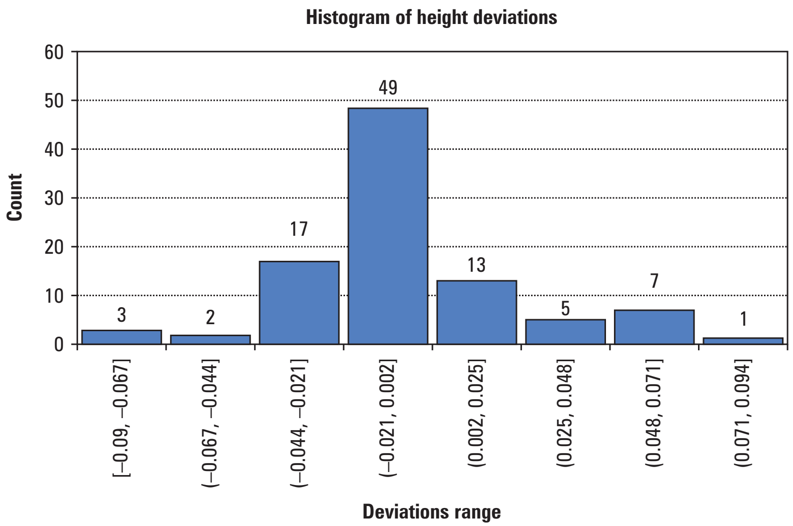


Source: Authors' own study

Fig. 12. Deviations in height ΔH for the Stelmachów Street

7. Final conclusions

From the analyses conducted for three research objects, it can be concluded that the works related to the preparation and provision of data for the construction of DTM have been carried out very accurately. In no case the permissible height error of 0.1 meter was exceeded for the studied population. The empirical distribution of elevation deviations is similar to that of the Gauss distribution (Fig. 13). The standard deviation is $\delta = 0.030$ meters.

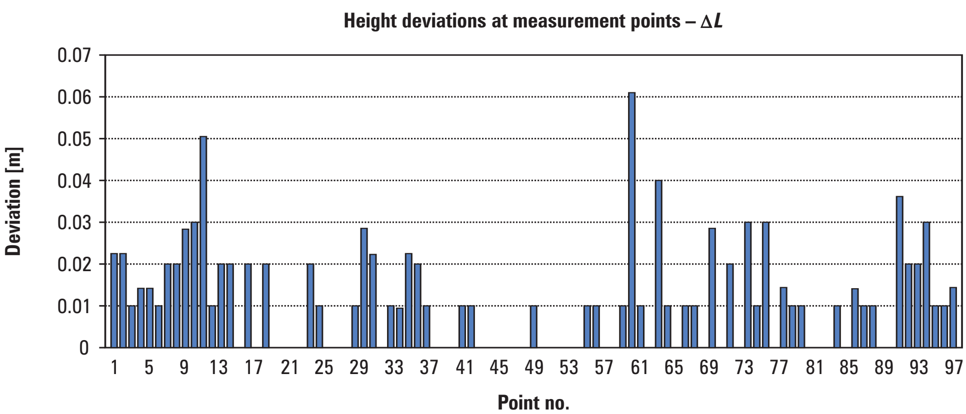


Source: Authors' own study

Fig. 13. Deviations in height Δ*H* for the whole of the research

In the final analysis, data from all 3 objects were intentionally combined. The authors are aware of the differences resulting from the variation in the LIDAR data. However, the intention was to average out the entire research process, realising that in a classic measurement within a single study, this will very often be the case.

The average linear deviation for the studied population of 97 points was 0.010 meters (Fig. 14). This proves a very accurate mapping in the field of the cloud points selected for analysis. The standard deviation is δ = 0.012 meters.



Source: Authors' own study

Fig. 14. Deviations in length Δ*L* for the entire research

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