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FORMATION OF A DENSE CLOUD OF POINTS AND ITS PROCESSING WHEN CREATING A DIGITAL MODEL OF THE TERRAIN

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Annotation. *The article explores the creation of digital terrain models (DRMs) based on dense point cloud classification in QGIS, Digitals, and 3D Survey software.*

In the research process, a dense cloud of points created during 3D scanning of the territory of the botanical garden of NULES of Ukraine was used, followed by classification and construction of digital relief models in various software tools.

The stages of point cloud classification, creation of classification layers, data export to QGIS, Digitals and 3D Survey software tools for further modeling and drawing of models with isolines were studied.

The digital model of the relief and the stages of its creation, "cleaning" of the original cloud of points of different density are considered.

On the basis of the same initial data, a dense cloud of points, the formation of digital models of the relief of the territory of the botanical garden of NUBiP of Ukraine was carried out in various software tools.

The process of creating a digital relief model was investigated based on a dense point cloud using QGIS, Digitals, 3D Survey programs.

The main advantages and disadvantages of building a digital relief model based on a cloud of points formed by the results of 3D scanning are analyzed.

Features and capabilities of software tools QGIS, Digitals, 3D Survey and their ability to build 3D surfaces based on exported point clouds are considered.

Keywords: *digital terrain model, QGIS, digital survey, 3D survey, 3D model, 3D scan, 3D Survey, QGIS, Digitals, point cloud, isoline, construction of horizons.*

Statement of the problem.

Unmanned aerial vehicles (UAVs) and mobile 3D scanners have become widely used and widely used at the current stage of development of geodesy and geoinformatics in the world. The list of tasks that can be solved with their help grows every year.

Various types of measurements, their processing and creation of digital relief models are an urgent task in the field of geodesy, cartography and land management. UAVs used for geodesy purposes provide accurate data on the features of the terrain, the situation, the built-up area, but are limited in their application in war conditions, therefore the formation of a dense cloud of points by the method of 3D scanning of the territory and its processing when creating a digital model of the terrain is an extremely urgent task in the present time and makes it possible to use them in performing geodetic works of various types.

Terrestrial 3D scanning has no limitations in its application, although it has lower performance in planar surveying than UAV applications.

Digital relief model (DRM) is a means of representing the topographic (earth) surface during computer processing of the results of engineering and geodetic surveys. With the help of a digital relief model, such applied problems as construction of horizontal lines, obtaining longitudinal and transverse profiles, calculation of volumes of earth masses, etc. are solved. Processes of surface modeling are taken into account when designing general plans, with the help of a digital 3D model of the existing terrain, the task of calculating and optimizing the volume of moved soil is solved [1].

A digital terrain model (Digital Terrain Model) shows the height, location and shape of the earth's surface without taking into account vegetation, infrastructure and man-made objects. Digital terrain models are created on the basis of classified point clouds, which are obtained using 3D scanning or photogrammetric methods, and the information used and its reliability are determined by the set goal and task for a certain type of work.

Analysis of recent research and publications.

Research on this topic was conducted by many authors, in particular:

- Bursztyńska H. conducted a comparative analysis of the accuracy of DEM construction using the Surfer program package and geographic information of the ArcGIS system [3].

- Burachek V. presented the means of geoinformative analysis of spatial data, considered modern technologies of geospatial information processing. Highlighted the views of domestic and foreign specialists regarding the possibility of modern analytical processing in geoinformation systems. Described the models and algorithms that form the basis of geoinformational analysis of spatial data. Considered software implementation, integration of data and technologies [2].

- Butenko Ye., Borovyk K., Geryn A., Gubkin B. AND. investigated the use of digital relief models (DRM), their classification and the method of obtaining them in the Civil 3D software [1].

- Byalyi M. "considered the existing models and methods of building digital relief models with the aim of their comparative analysis based on the integration of open, publicly available sources of information. Listed approaches to building digital relief models and considered information support for their creation" [5].

- D. Groholsky highlighted the technology of laser scanning data processing in the software product "CREDO 3D SCAN". The main attention was devoted to the classification of point clouds [6].

- V. Zatserkovnyi presented the conceptual foundations of GIS, the purpose and principles of GIS construction, considered modern geospatial information processing technologies, the models underlying them, modern directions of GIS application and development prospects. Considered software implementation, integration of data and technologies [7].

- Ravi P. Gupta considered the formation of dimension matrices for raster GIS [10].

- Szypuła B. studied the process of creating digital relief models in the ArcGIS software [11].

The listed studies laid the methodological basis for the construction of DEM and various methods for creating 3D models.

The question of creating a digital terrain model and its application remains relevant, since there are various software tools for creating a DEM when solving different problems with different accuracy.

The purpose of the study.

The purpose of the study is to study the basics of forming a dense cloud of points and further work with it using QGIS, Digitals and 3D Survey software when creating a digital relief model.

Materials and methods of scientific research.

The following methods were used during the scientific research: monographic, abstract-logical, modeling, calculation and generalization methods.

The application of the monographic method consisted in the study and familiarization with scientific works, articles, monographs, scientific publications related to the development of the DEM. On the basis of the studied sources, the authors of the study determined for themselves the main aspects, tasks and order of further research.

The abstract-logical method was applied in the analysis of the technology of obtaining digital information about the topography of the territories and the creation of the height base. The creation of DEM is based on the construction of TIN models, the introduction of clarifying skeleton lines and the correct classification of a dense cloud of points, relief modeling algorithms within the scope of the study, using QGIS, Digitals, 3D Survey software complexes.

Using the modeling method, adaptive thinning was performed on a previously formed dense point cloud of the earth's surface, which allows for the formation of a height frame of territories consisting of key points that determine the existing topography of the area. The minimum number of points will remain on the leveled and related parts of the surface, and the number of points necessary to convey the shape of these objects will be preserved on the fractures and microforms of the relief. The key relief points classified in this way inside the cloud form the "skeleton" of the surface [6].

The use of the calculation method consisted in calculating the deviations and determining the coefficient of variation of the position of the horizontal lines that characterize the topography of the area. Having calculated the values of the arithmetic mean deviation and the mean square deviation, the authors of the study determined the coefficient of variation, which indicates the level of variability of the horizons and the accuracy of their construction.

After analyzing the works of scientists by topic and conducting modeling of the construction of the DEM in software tools, based on the basic object of the study, after performing calculations, we determined the optimal software tool for the construction of the DEM when solving problems of geodesy and land management.

Research results and their discussion.

Currently, spatial information is increasingly used in various fields of science and technology, and its effectiveness, accuracy, and availability are increasing every day due to the development of modern tools for their acquisition and further interpretive processing.

This is facilitated by the growing availability of data, the creation of heterogeneous databases, the emergence of more powerful computers and global digitalization.

In recent years, geoinformation systems and web services containing spatial information have occupied a special place in the world of information technologies.

The digital terrain model provides information on the height of the earth's surface and special topographical information, data on soil cover, slope type, cross-section of the terrain and regional terrain features [8].

Digital terrain models play a fundamental role in spatial planning, engineering and have a wide range of practical applications.

DEM is understood as a three-dimensional mathematical model of the Earth's surface, which is presented in the form of an array of points with a certain height for the entire area of distribution in the studied territory.

DEM is necessary for obtaining the most detailed information about the topography of a certain territory, "when updating digital topographic maps and plans of various scales, when performing various types of engineering surveys, geological studies, biological and spatial studies" [5].

Solving the problem of increasing the accuracy of the display of surface irregularities will allow us to determine the appropriate method of creating digital relief models, as the most optimal, fast, accurate, in the process of classifying the source cloud of points in QGIS, Digitals and 3D Survey software tools.

"The digital model of the relief is presented in the form of a relief matrix of the heights of the Earth's surface. This matrix representation is commonly used in telecommunications projects and is provided in the format of RF planning tools such as: Planet, Atoll, ATDI, etc.

The TIN model (TIN - Triangulated Irregular Network) is a vector representation used in GIS projects in the form of OBJ, 3DS, VRML, DXF, Google Earth KMZ files [2].

DEM is one of the important map layers for spatial interpretation purposes. It is also widely used as a basis for solving the following tasks:

- landscape planning of the territory;
- urban planning;
- highway construction;
- railway construction;
- flood modeling;
- geological analysis;
- geodesy and land management.

The use of digital models significantly reduces time and labor costs compared to the traditional technology of obtaining marks from topographic plans and the instrumental method.

The object of the study was the territory of the basic ZVO - NULES of Ukraine, namely the botanical garden, as an object with a pronounced relief and difficult to capture geobotanical indicators and further data processing. The height difference is 40 meters, the terrain is hilly. Vegetation is present, which complicates the application of classical photogrammetric methods. The specified object covers an area of 53 hectares, bordering the protected territory of the Holosiivskyi National Nature Park [4].

In the process of research, three stages of work were defined:

1. shooting of the research object;
2. preparation of a dense cloud of points;
3. processing of shooting in software tools.

Surveying of the research object takes place with the help of a 3D scanner AlphaGEO SLAM R100 with a density of 320,000 / 640,000 t/s and marking of 28 reference points for more accurate reference of the cloud of points in the USK 2000 system of coordinates and heights.

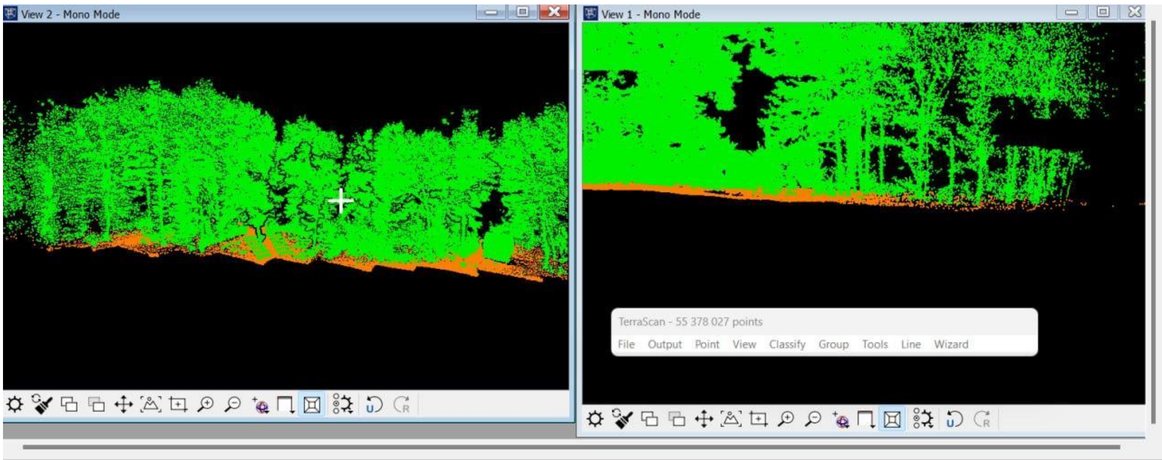

Figure 1. A photo of a dense point cloud of the territory of the botanical garden of the NULES of Ukraine, captured by a 3D scanner in the viewer

On the basis of the received spatial data, we remove building points, points of adjacent objects, trees and bushes from the cloud of points (Fig. 1). The 3D model was created based on the colorization of a dense cloud of points and the creation of a continuous surface based on discrete points with the elimination of geometric distortions caused by the shooting conditions.

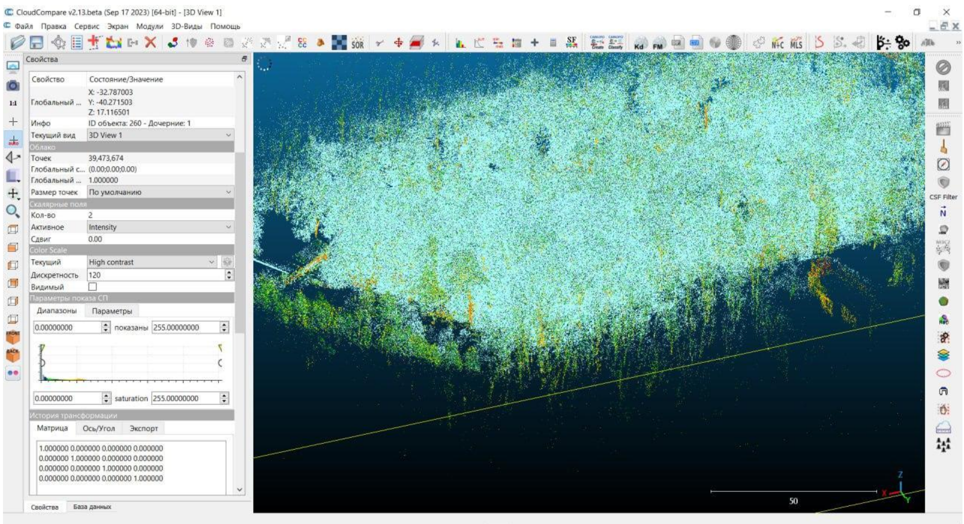

Figure 2. Photo of dense point cloud classification in CloudCompare program

The final goal of the study was to create a digital model of the relief in various software tools, transform the processed data into a visual representation of the relief and assess the accuracy of the results.

During the creation of DEM based on a cloud of points, the first task is the selection (classification) of relief points from a dense cloud of points belonging to the earth's surface (Fig. 2.). Existing distortions and artificially created points due to "noise" can lead to incorrect relief classification, so it is necessary to first remove them or classify them as noise and remove them from further processing [6].

Before starting the work, the cloud of points must be coordinated and improved for the further creation of a three-dimensional model.

The improvement of the point cloud involves the improvement of that part of the cloud of points that overlaps when scanning with a 3D scanner from different spatial positions on the object, in order to form another, more accurate and dense cloud of objects and capture the image of the entire area of the object.

The program changes the provided point clouds into structured elements representing the surface of the scanned object. Some of the collected points were not used in further processing. The final processing involved "cleaning" the cloud from noises and their further removal [6].

Processing speed largely depends on the density of the cloud of points and the power of the computer used for processing.

We export processed dense cloud data with a classified layer of the Earth's surface to software tools QGIS, Digitals, 3D Survey for further processing and construction of DEM in each of these tools.

1.Creating a digital terrain model in QGIS software.

At the initial stage of work, we download the Shapefile of the dense point cloud of the 3D scan of the territory to the QGIS software tool (Fig. 3).

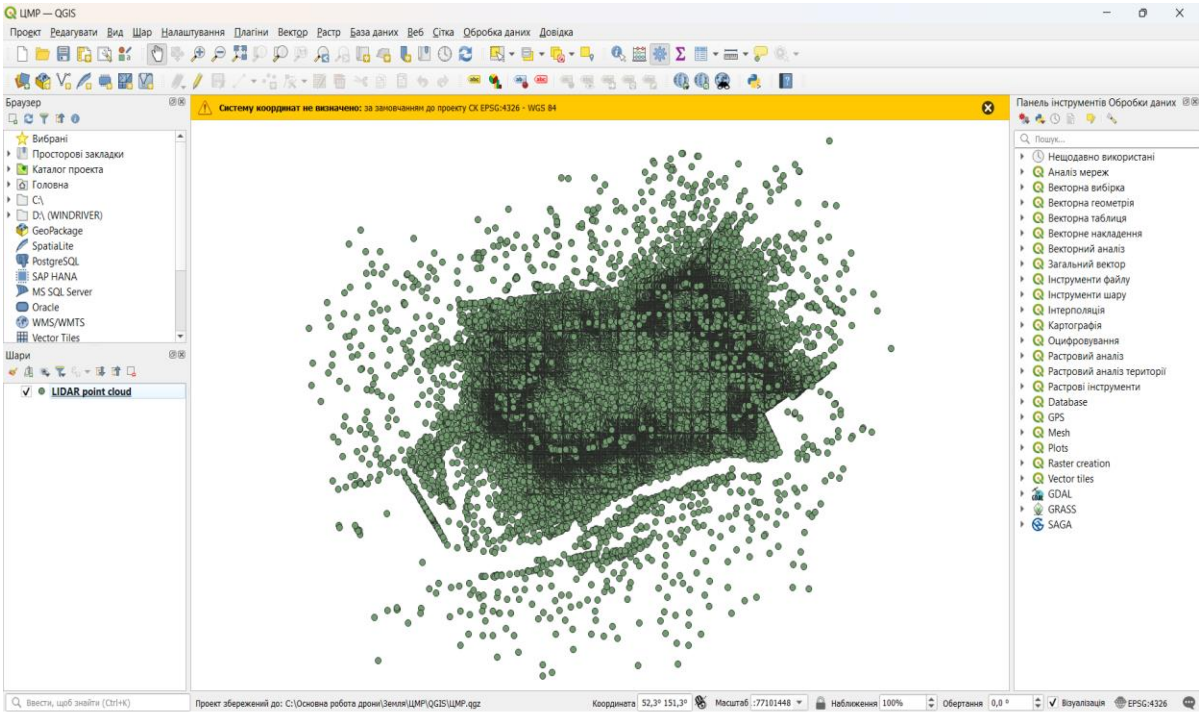

Figure 3. Point cloud in QGIS software

As a result of data processing, a digital model of the terrain was built, which for better analysis and visualization can be presented in the form of a colored model (Fig. 4).

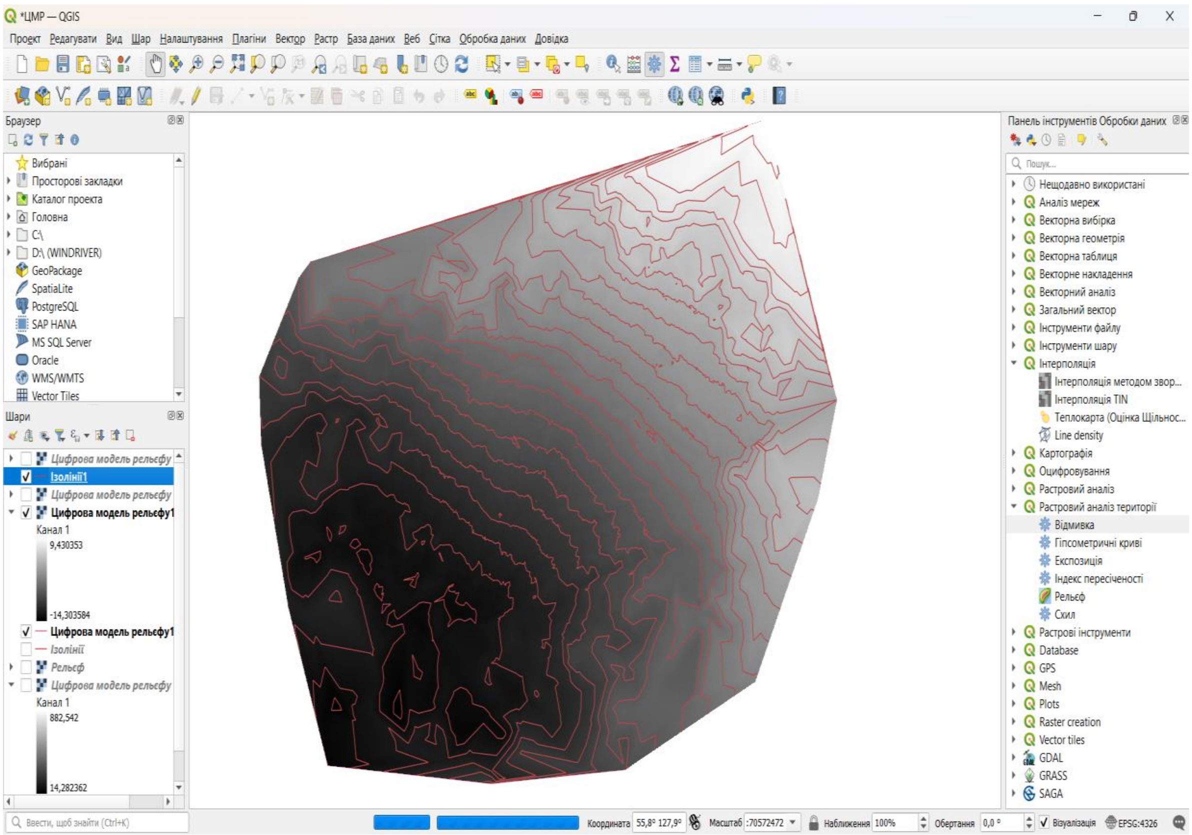

Figure 4. Digital terrain model in QGIS software

2. Creating a digital terrain model in Digitals software.

We download the dense cloud of points, obtained with the help of 3D scanning of the territory (Fig. 5), to the software tool Digitals, we carry out the necessary stages of its processing when creating the DEM.

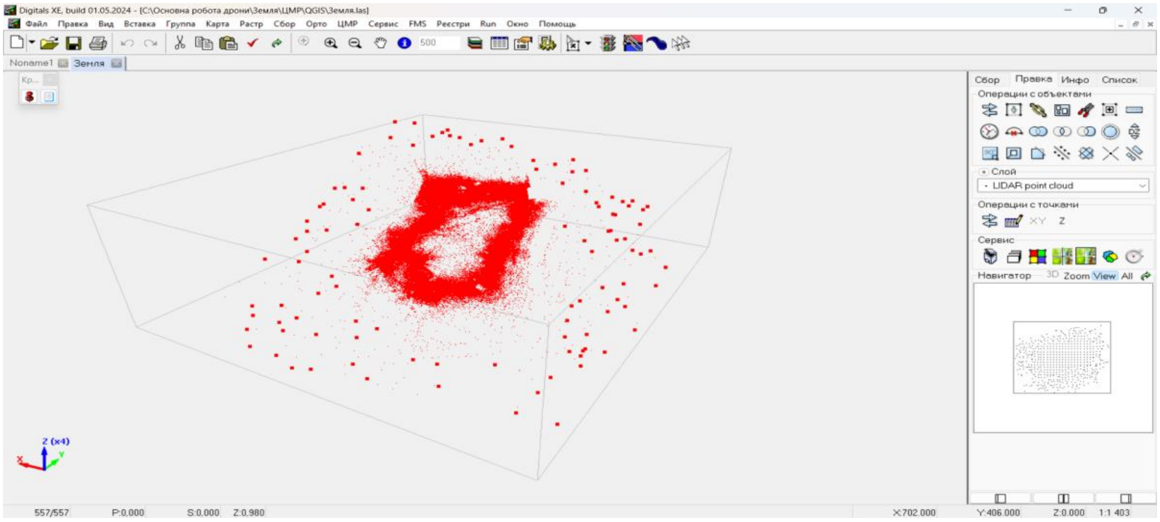

Figure 5. Point cloud in Digitals software

Having formed the DEM with a step of 1 meter, for visualization in 3D space, we choose the "three-dimensional" view of the object and draw the horizontal lines (Fig. 6).

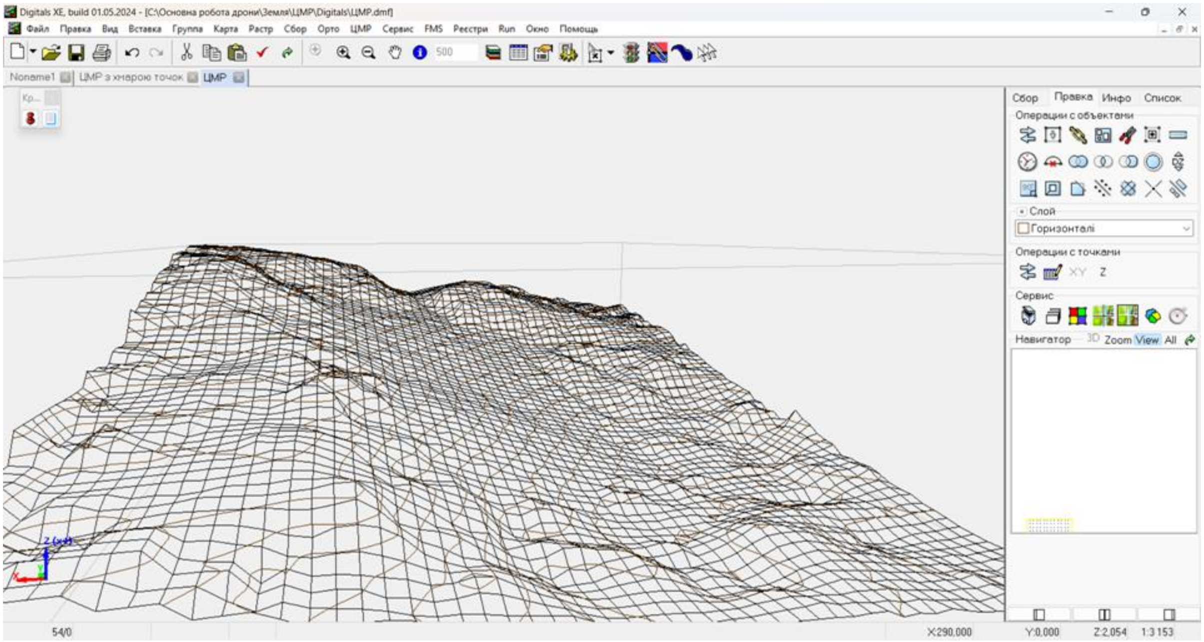

Figure 6. Digital terrain model in Digitals software

3. Creating a digital relief model in 3D Survey.

According to a similar algorithm of actions, a digital relief model is created in the 3D Survey software (Fig. 7 and Fig. 8).

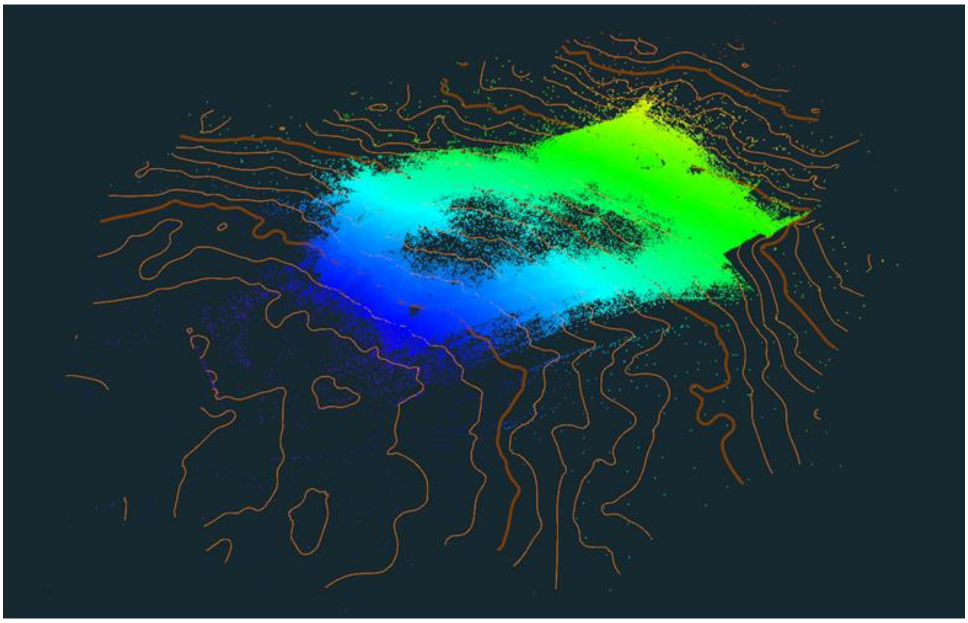

Figure 7. Point cloud in 3D Survey software

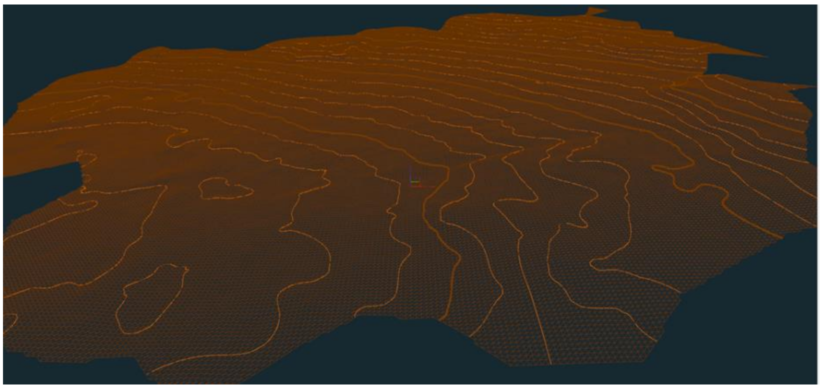

Figure 8. Digital terrain model with construction of horizons in 3D Survey software

In order to understand how different the lines of equal heights (horizontals) are that we obtained in the digital relief models of various software tools (Fig. 9), a calculation was made and the coefficient of variation was determined, which shows how much the values on these models differ. The smaller this indicator is, the more precisely the horizontal lines coincide. This helps us to assess how accurately the modeling work is done and which of them can be used to solve geodesy and land management tasks.

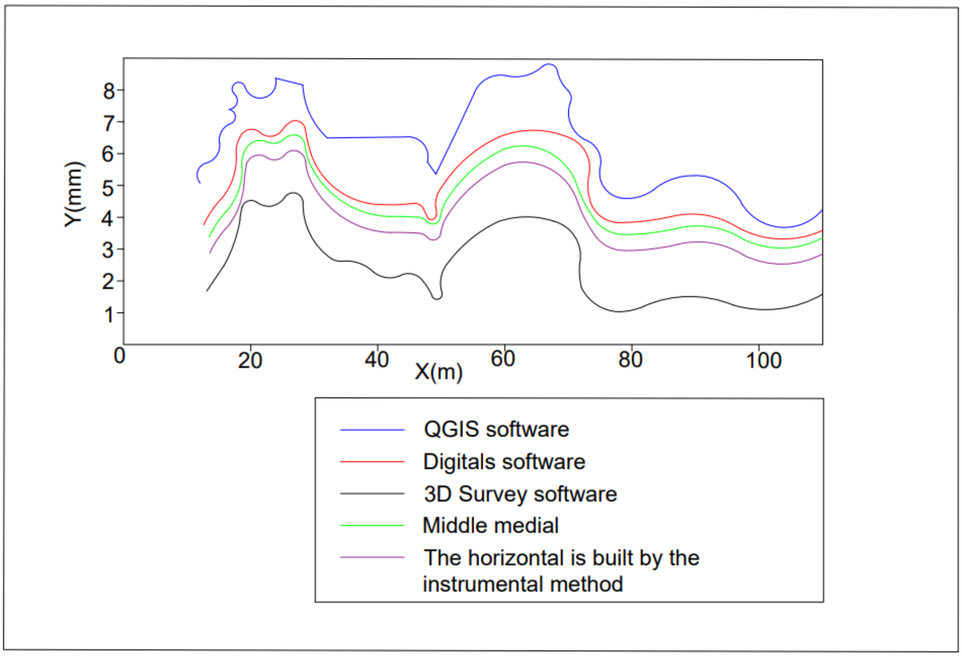

Figure 9 The results of the construction of horizons in digital relief models obtained in various software tools with the display of the medial value

"The coefficient of variation is a relative value that serves to characterize the dispersion (variability) of a feature.

The coefficient of variation characterizes the uniformity of the population and the degree of reliability of the calculation of average values" [9].

$$\vartheta = \frac{S_o}{\underline{S}} \cdot 100\% \quad (1)$$

The average arithmetic deviation is determined by the formula:

$$\bar{S} = \sum_n^i = \frac{y_i - y_i'}{n} \quad (2)$$

where: $\bar{S}$ – average arithmetic deviation;

n - number of counts;

y_i – value by coordinate O_y graph of the corresponding function i reference on the final horizontal;

y_i' - the value on the O_y coordinate of the graph of the function, which corresponds to the i-th reference on the previous horizontal.

$$\bar{S} = 1{,}956254 \text{ [m]}.$$

The mean square deviation is determined by the formula:

$$S_0 = \sqrt{\frac{1}{n-1}(y_i - \bar{S})^2} \quad (3)$$

де: S_0 – mean square deviation;

n – number of counts;

y_i – the value on the O_y coordinate of the graph of the function, which corresponds to the i-th reference on the final horizontal;

$\bar{S}$– arithmetic mean deviation.

$S_0 = 0{,}235489$ [mm].

Having obtained the values of the arithmetic mean and the mean squared deviations, we determine the coefficient of variation:

$$\vartheta = \frac{0{,}235489}{1{,}956254} \cdot 100\% = 12{,}04\%$$

The level of variability is usually assessed on a scale: less than 10% - low level, from 11 to 25% - medium level, more than 25% - high level.

The analysis showed that the variability of horizontal lines is within the medium level. The most accurate result of DEM in comparison with the classic instrumental method of building horizons is obtained in the Digitals software; an approximate version corresponding to the medial value tolerance is in the DEM created in 3D Survey.

Conclusions. The creation of a high-quality digital model of the terrain is the key to effective management, the formation of a reliable plan-elevation basis for designing and modeling various processes and predicting their consequences.

Based on the results of the research, it can be concluded that the accuracy of the construction of the DEM corresponds to the accuracy of the work. Therefore, the removal of areas with high grassy and bushy vegetation must be carried out in early spring or autumn under leafless cover and the absence of grassy vegetation, which will reduce the impact of inaccuracies on the result of constructing the DEM.

Analysis of the obtained digital terrain models in such software tools as QGIS, Digitals and 3D Survey gives reason to conclude that the best terrain is displayed in the DEM in the Digitals software; an approximate version corresponding to the tolerance of the medial value of the DEM is created in 3D Survey. From the data obtained at the research site, we can see that the relief is highly dissected and hilly, but the use of modern software tools for building a digital model of the relief provides the necessary level of accuracy for further work based on the created DEMs.

References

1. Butenko, E. V., Borovik, K. V., Herin, A. R., & Gubkin, B. A. (2020). Formuvannya tsyfrovoï modeli relyefu za materialamy aerofotozjomky v programnomu zasobi CIVIL 3D [Formation of a digital terrain model based on aerial photography materials in the CIVIL 3D software], Land Management, codastrs and Land Monitiring, 2-3, 156 – 168.

DOI: https://doi.org/10.31548/zemleustriy2020.02.16

2. Botanical Garden of the National University of Life and Environmental Sciences of Ukraine. Wikipedia. Available at: http://surl.li/kycdvz

3. Burachek, V. G., Zhelezniak, O. O., & Zatserkovnyi, V. I. (2011). Geoinformatsiinyi analiz prostorovykh danykh [Geoinformation analysis of spatial data]. TOV “Vydavnytstvo “Aspekt-poligraf”, 440.

4. Burshtynska, H. V. (2003). Teoretychni ta metodolohichni osnovy tsyfrovoho modeliuvannia relyefu za fotogrammetrychnymy ta kartometrychnymy danymy [Theoretical and methodological foundations of digital terrain modeling based on photogrammetric and cartometric data] (Doctoral dissertation). Natsionalnyi universytet “Lvivska politekhnika”, 36.

Available at: http://www.disslib.org/teoretychni-ta-metodolohichni-osnovy-tsyfrovoho-modeljuvannja-relyefu-za.html

5. Bialiy, M., Savkov, P. (2023). Zastosuvannia radarnoi interferometrii dlia pobudovy tsyfrovykh modelei relyefu [Application of radar interferometry for the construction of digital terrain models]. Collection of scientific works of the Military Institute of Taras Shevchenko National University of Kyiv, 79, 76 – 93.

DOI: https://doi.org/10.17721/2519-481X/2023/79-08

6. Grokholskyi, D. Klasyfikatsiia khmar tochok i stvorennia tsyfrovoï modeli mistsevosti v noviy versii programy CREDO 3D SKAN [Classification of point clouds and creation of a digital terrain model in the new version of the CREDO 3D SCAN program]. 39, 53-59.

Available at: https://ena.lpnu.ua:8443/server/api/core/bitstreams/543bf0b3-3eb4-4d14-987b-e7d812acf44f/content

7. Zatserkovnyi, V. I., Burachek, V. G., Zhelezniak, O. O., Tereshchenko, A. O. (2017). Geoinformatsiini systemy i bazy danykh [Geographic information systems and databases]. NDU im. M. H. Gogola, 237.

Available at: file:///D:/Users/User/Desktop/%D0%97%D0%B0%D1%86%D0%B5%D1%80%D0%BA%D0%BE%D0%B2%D0%BD%D0%B8%D0%B9%20%D1%82%D0%B0%20%D1%96%D0%BD.%20"%D0%93%D0%B5%D0%BE%D1%96%D0%BD%D1%84%D0%BE%D1%80%D0%BC%D0%B0%D1%86%D1%96%D0%B9%D0%BD%D1%96%20%D1%81%D0%B8%D1%81%D1%82%D0%B5%D0%BC%D0%B8%20%D1%96%20%D0%B1%D0%B0%D0%B7%D0%B8%20%D0%B4%D0%B0%D0%BD%D0%B8%D1%85.%20%D0%9A%D0%BD.%202".pdf

8. Li, Z. L. (1990). Strategy for sampling and accuracy assessment for digital terrain modelling (Doctoral dissertation). University of Glasgow. 24. Available at: https://nguyenduyliemgis.wordpress.com/wp-content/uploads/2014/11/digital-terrain-modeling-principles-and-methodology_2005.pdf

9. Indicators of variation. Indicators of variation and methods of their calculation. Available at: https://elib.lntu.edu.ua/sites/default/files/elib_upload/%D0%A2%D0%B0%D0%BB%D0%B0%D1%85%20%D0%A1%D1%82%D0%B0%D1%82%D0%B8%D1%81%D1%82%D0%B8%D0%BA%D0%B0/page13.html

10. Ravi P. Gupta. (2018). Digital elevation model. Remote Sensing Geology, 3, 101-106. Available at: https://books.google.com.ua/books?id=lERADwAAQBAJ&printsec=frontcover&hl=uk&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

11. Szypuła, B. (2017). Digital Elevation Models in Geomorphology. In D. Shukla (Ed.), Hydro-Geomorphology - Models and Trends (pp. 81-112).

DOI: 10.5772/intechopen.68447

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ФОРМУВАННЯ ЩІЛЬНОЇ ХМАРИ ТОЧОК ТА ЇЇ ОПРАЦЮВАННЯ ПРИ СТВОРЕННІ ЦИФРОВОЇ МОДЕЛІ РЕЛЬЄФУ

Анотація. *У статті досліджено створення цифрових моделей рельєфу (ЦМР) на основі класифікації щільної хмари точок у програмних засобах QGIS, Digitals і 3D Survey.*

У процесі дослідження використано щільну хмару точок створену при 3D скануванні території ботанічного саду НУБіП України із подальшою класифікацією та побудовою цифрових моделей рельєфу у різних програмних засобах.

Досліджено етапи класифікації хмари точок, створення класифікаційних шарів, експорт даних до програмних засобів QGIS, Digitals та 3D Survey для подальшого моделювання та прорисовки моделей ізолініями.

Розглянуто цифрову модель рельєфу та етапи її створення, «чистки» вихідної хмари точок різної щільності.

На основі однакових вихідних даних щільної хмари точок, здійснено формування цифрових моделей рельєфу території ботанічного саду НУБіП України у різних програмних засобах.

Процес створення цифрової моделі рельєфу досліджено на основі щільної хмари точок за допомогою програм QGIS, Digitals, 3D Survey.

Проаналізовано основні переваги та недоліки побудови цифрової моделі рельєфу на основі хмари точок, сформованої за результатами 3D сканування.

Розглянуто функції та можливості інструментів програмних засобів QGIS, Digitals, 3D Survey та їх здатність будувати 3D поверхні на основі експортованих хмар точок.

Ключові слова: *цифрова модель рельєфу, QGIS, цифрова зйомка, 3D зйомка, 3D модель, 3D сканування, 3D Survey, QGIS, Digitals, хмара точок, ізолінія, побудова горизонталей.*