

REALIZATION OF THE ORTHOPHOTO PLAN, THE DIGITAL TERRAIN MODEL (DTM) AND THE SURFACE (MDS) FOR COMPLETION/REVISION OF THE FEASIBILITY STUDY, ELABORATION OF THE TECHNICAL PROJECT, FOR THE "BUCHAREST - BRAŞOV HIGHWAY, PLOIEŞTI - BRAŞOV SECTION"

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Abstract: *A feasibility study is based on a detailed topographic survey that describes very well the configuration of the terrain on the altitude, but also the possibility to determine any object in Stereographic 1970 coordinates necessary for detailed studies. The method of carrying out topographic surveys can be based on classic or modern technologies, which ensure uniformity, precision and a large number of points per surface unit. Combined technology was chosen, photogrammetric flight with high-resolution camera, but also LiDAR data. By combining these two technologies, the best results can be obtained. Of course, field measurements are also needed to determine control points (Ground Control Points - GPC) or landmark. Checkpoints for the accuracy of the orthophotoplane and the MDT and MDS were also determined. Special point cloud processing programs were used.*

Keywords: *Technical Project; orthophoto plan; Digital Terrain Model*

1. Introduction

The need to build highways is indisputable in any country. In Romania, the rate of completion of these constructions is very slow and full of obstacles. The completion of the Bucharest - Braşov highway has been discussed for decades and only the easiest section, Bucharest - Ploieşti, has been completed. For the rest, several feasibility studies were carried out that were never put into practice.

Upon receiving the order, we considered that the creation of the topographical plan that will be the basis of the design must be done at the highest possible quality in order to avoid any subsequent problems during the actual construction.

The orthophoto plane is an aerial image/ a set of geometrically and radiometrically corrected mosaic (merged) aerial images, obtaining a representation of the terrain at a uniform scale (Barnes, 2018).

LiDAR (Light Detection And Ranging) laser scanning is an innovative technique for taking altitudes, with special perspectives in applications in the field of photogrammetry (Paunescu, 2019). A scanner can provide enough points of known X,Y,Z coordinates so that the topographic surface can be modeled (digital altimetry model, digital terrain model, contour generation).

2. Realization of the work

2.1. Technology used

In order to carry out the work Completion/Revision of the Feasibility Study, elaboration of the Technical Project, for the "HighwayBucuresti - Braşov, section Ploieşti - Braşov" an action plan was developed which includes both the creation of an orthophoto plan and the generation of digital models of the land and surface for the area of interest, exploiting the data collected following the performance of specific aero-photogrammetric flights. The system used for data acquisition consisted of:

- LiDAR: RIEGL VQ-780iis (based on RIEGL Waveform-LiDAR technology, the system features a high laser pulse repetition rate of up to 2 MHz, resulting in up to 1.33 million measurements / sec on the ground, parallel scan lines and uniform distribution of points)(RIEGL, 2022).
- Camera: DigiCam 150 / 50 mm RGB + DigiCam 100 / 50 mm NIR IMU/GPS System: IGI SMU AeroControl(IGI, 2022)
- Software: Riegl Package (RiACQUIRE; RiPROCESS; RiWORLD; RiMTA; RiPRECISION)

mounted on a Tecnam 2006T aircraft(RIEGL, 2022).

2.2. Realization of the orthophoto plane and MDT and MDS

The project will consider the following conditions:

1. Longitudinal and transverse coverage between frames and strips, depending on the products we will obtain, also the height and speed of flight;
2. The orientation of the photogrammetric strips is calculated;
3. A flight chart indicating the optimal flight period and hours of the day depending on the angle of inclination of the sun.
4. Retrieving information from the National Institute of Meteorology and Hydrology for the weather.
5. According to the above, the final route of the flight is established. It is handed over to the pilot and accompanying camera operator.

In order to comply with the established requirements, a flight was designed to ensure both the density of LiDAR points, necessary for the creation of digital models, as well as the specific overlaps of the frames in order to process the orthophoto plane.

It thus highlights 24 flight lines that have been correlated to be able to extract all the necessary details.

Flight performance is accomplished by designing a flight mission that specifies flight data and aerial photography.

In the next phase of LiDAR data validation, noise points were isolated and the density of points per square meter was analyzed, establishing compliance with the requested requirements.

In order to be able to georeference the orthophoto plane and bring the cloud of points into ground coordinates, landmarks (Ground Control Points - GCP) are needed.

The determination of the GCP is the stage that constitutes the basis for the realization of the mathematical link between the terrain and the photogrammetric images. Landmarks are points existing or materialized in the terrain so that they can be identified and scored in the

retrieved images (Tal & Altschuld, 2022). Terrain coordinates are determined by different methods. Determination of GCP are in 3D space (X,Y,Z).

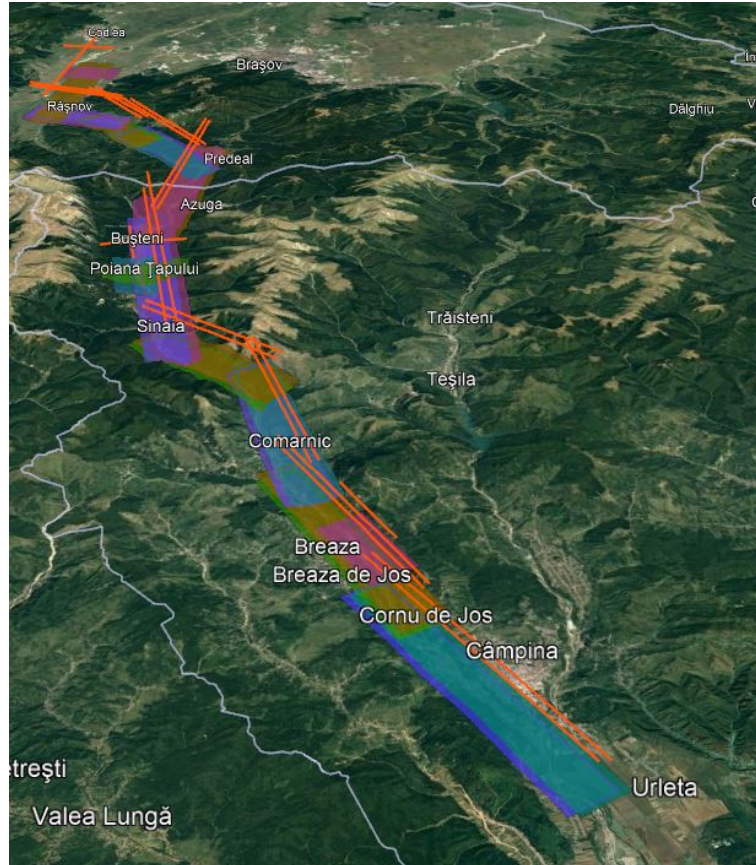


Fig. 1. Route of the future highway; the design of photogrammetric tapes

Natural landmarks involve the use of easily identifiable points on images and in the field such as: concrete platform corner, road marking, fence corner, bridge head, etc (Torleàrrd, 1986).

Artificial landmarks are applied where the terrain does not present details that meet the requirements of shape, size and position in the frame plan(Torleàrrd, 1986). They are done by pre-marking the GCP in the field before the flight. GCP pre-marking in the field is usually done with weather-resistant paint and in areas that allow marking: concrete platforms, asphalt roads, etc., or plastic models.

Constraints are made on these points and the precision with which the orthophoto plane and the digital model was made is obtained. The layout of the benchmarks is shown and the accuracy of these points after the constraint is shown in figure 2.

Checkpoints were also determined. As a density value greater than 16 pct/m² is recorded in the area of interest, the next stage was carried out, which involves checking compliance with the tolerances imposed for altimetric accuracy.

In this sense, specific calculations were made on the verification points (points that were not used in the constraint of the models) that demonstrated the correct technical fit of the data.

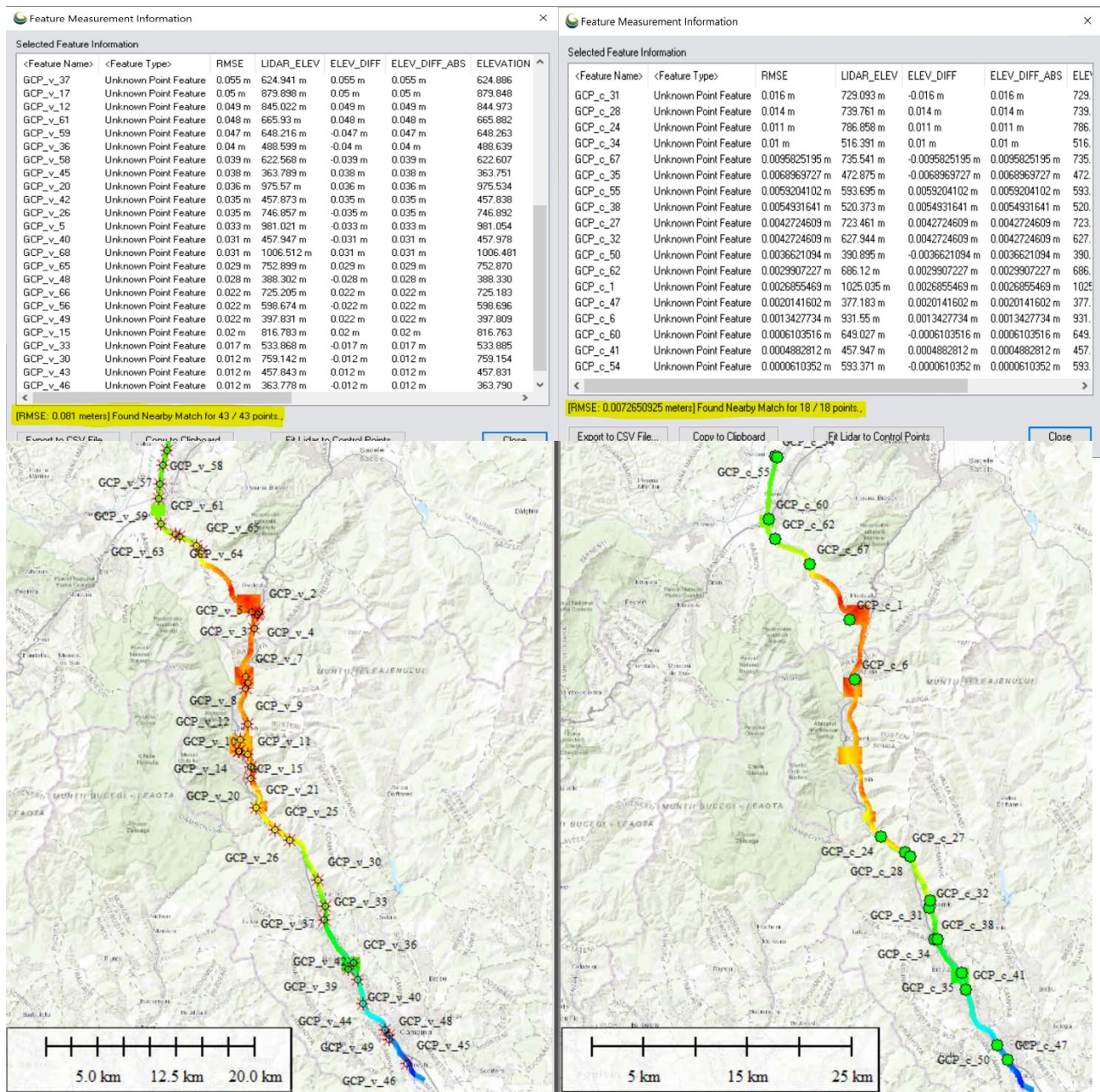


Fig. 2. GCP layout and accuracy obtained after constraint

Following the data validation, we moved on to the point classification stage for the isolation of those belonging to the process soil class, which was carried out using the TerraSolid suite.

The classification procedure consists of two main steps. Automatic classification, achieved by consecutively running some filters with preset parameters and the manual corrections that are necessary to eliminate certain errors caused by the rigidity of the filters(TerraSolid, 2022). To achieve the first stage, a "macro" type file is created in which the filters to be used, their parameters, the processing order and finally the command to save changes are registered. In this way, the "noise" points, which are either too high compared to

the general average or too low, are automatically classified in the first place. Then the points that belong to the ground, buildings, vegetation, high voltage poles, high voltage wires.

Unlike photogrammetrically determined points from overlay images, LiDAR points present a series of attributes that can be used in creating complex filters for rigorous classification. Thus the impulses can be classified or eliminated according to the scanning angle, intensity, time, echo value or the flight line of which it is a part.

Depending on the results thus obtained, the saved data can go through a subsequent filtering process or enter the stage of visual analysis and manual corrections. In this phase we have at our disposal a series of tools that facilitate the decision-making process of the operator and allow the reclassification of certain points to the appropriate classes.

Points can be moved from one class to another both in the main window and inside a predefined profile. The cloud of points can be manipulated for viewing in any direction. Moreover, the TerraModeler module has a function to create a dynamic surface that allows viewing the changes made to the point cloud in real time or even supports corrections directly on the surface (TerraSolid, 2022). This editable model recalculates the triangle mesh after each change to the point cloud being an important element in the interpretation process. The separation of points by classes of interest can be seen in Figure 3.

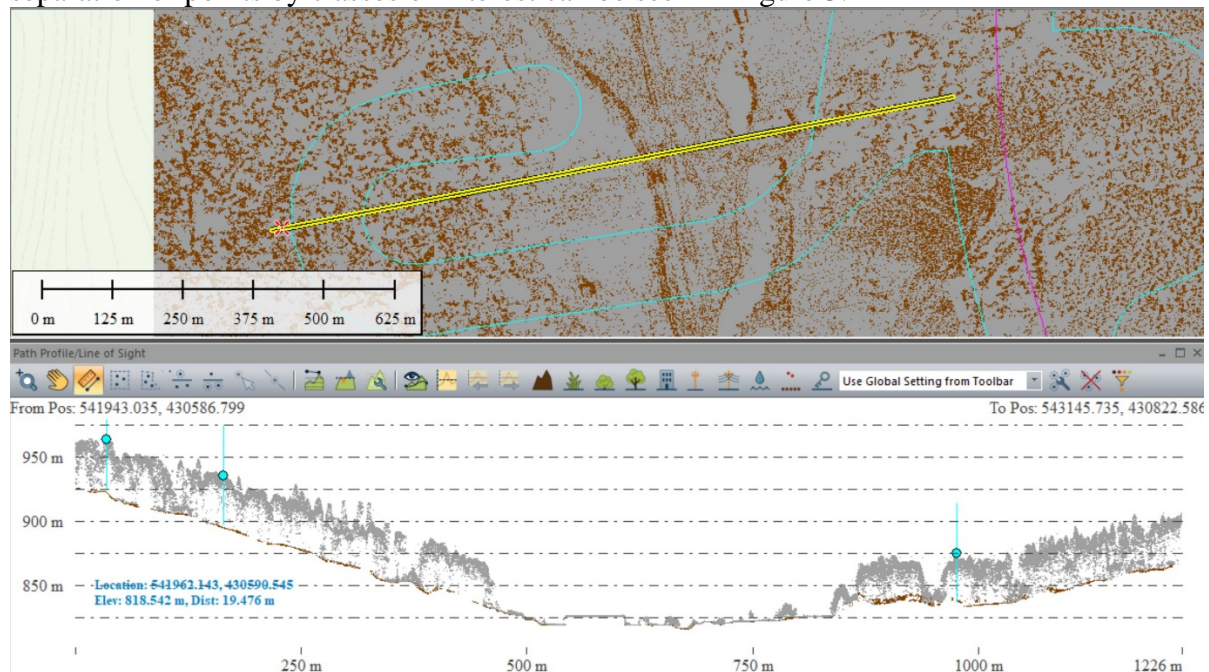


Fig. 3. Separation of points by classes

Checking the accuracy of the MDT uses check points, a digital terrain model from other sources, verified and approved, and even determined points on the terrain for which the elevation has also been determined (Brovelli, et al., 2004).

The TIN (Triangulated Irregular Network) network of non-uniform triangles containing point data connected in triangular facets was used to create the digital model. This requires a large number of points to generate a valid surface model.

After the classification of the ground points, we moved on to the generation of the digital models needed for the subsequent stages of the project.

The difference between the two types of models can be analyzed in Figure 4.

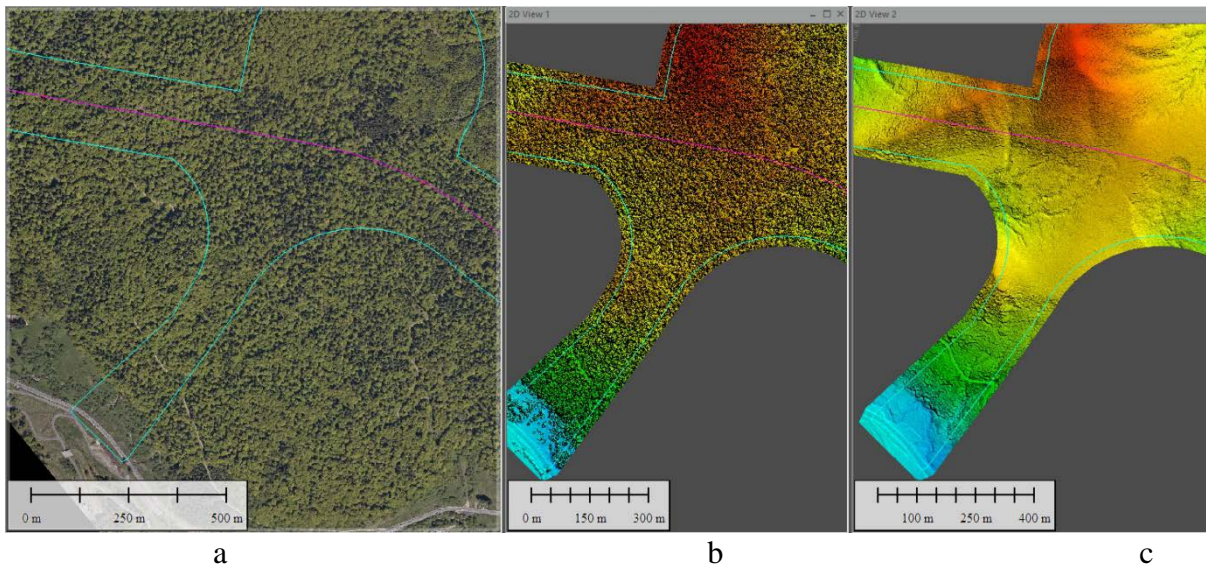


Fig. 4. a – orthophoto plane; b – Digital Model of the Surface; c – Digital Terrain Model

The importance of using LiDAR technologies in these types of projects is demonstrated by several aspects that are worth considering. On the one hand, we are talking about the relatively short time required for scanning. Then, using modern specific tools and suitable workstations, automatic classification and manual corrections can be performed accurately, validation and quality control presenting no major difficulties.

As can be seen in the image above, an extremely important advantage is the creation of digital land models for areas covered by vegetation(Cai & Rasdorf, 2008). As modern sensors can penetrate forested areas, the shape of the ground can be highlighted detailing the characteristics of the area of interest for use in subsequent calculations specific to these types of projects. This aspect would present serious challenges if one tried to use the classical methods of determining the surface of the land.



Fig. 5. The digital terrain model along the entire route

3. Interpretation of the results

The purpose of the work was the creation of an orthophoto plan and the Digital Model of the Land and the Surface in order to draw up the feasibility study and the technical project for the construction of the Ploiești - Brașov highway section.

This feasibility study and technical design serve as a basis for designers. Excavation and filling volumes are calculated, bridges, viaducts, tunnels are designed, where appropriate.

For this reason, the precision of determining the planimetric position, but especially the altimetric position, is very important. Any error can lead to increased costs or the wrong positioning of constructions.

Speaking of accuracy, we can discuss absolute accuracies and relative accuracies. The absolute accuracy is the accuracy with which we determined the value of the elevation of each point in the point cloud.

Relative accuracy is the accuracy with which the difference in level between two successive points in the point cloud obtained by scanning is determined.

The absolute accuracy (RMS) is the one shown in Figure 2. From here it can be seen that it does not exceed 5 cm per altitude, an accuracy that corresponds to the requirements of the beneficiary, considering that the terrain is uneven and uneven.

4. Conclusions

The method used to create the orthophoto plane and the Digital Land and Surface Model meets the required accuracy conditions.

From the resulting products the designer can obtain the necessary data for the necessary calculations. A topographical terrain profile can be generated between any two points in the Digital Terrain Model.

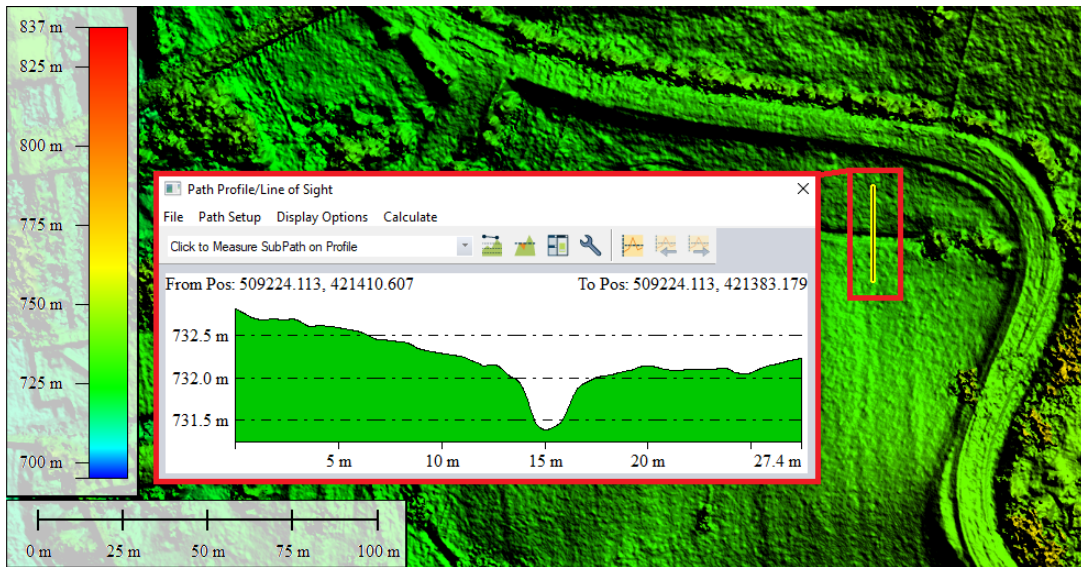


Fig. 6. Topographic profile of the land between two certain points

A detailed topographical plan can also be obtained in any area over which the flight was made. Existing objects on the ground can be represented (buildings, roads, railways, buildings, etc.). All these elements are essential in carrying out a feasibility study and a technical project according to the reality on the ground. The work was accepted and used by the designers.

5. Bibliography

1. Barnes, A., 2018. *Digital Photogrammetry. The Encyclopedia of Archaeological Sciences*, pp. 1-4.
2. Brovelli, M., Cannata, M. & Longoni, U., 2004. *LIDAR Data Filtering and DTM Interpolation Within GRASS. Transactions in GIS, Volume 8*, pp. 155-174.
3. Cai, H. & Rasdorf, W., 2008. *Modeling road centerlines and predicting lengths in 3-D using LIDAR point cloud and planimetric road centerline data. Computer-Aided Civil and Infrastructure Engineering*, 23(3), pp. 157-173.
4. IGI, 2022. www.igi-systems.com. [Online]
Available at: https://www.igi-systems.com/files/IGI/Brochures/DigiCAM/IGI-DigiCAM-150MP_specs.pdf
[Accessed 10 November 2022].
5. Paunescu, C. N. F. & P. V., 2019. *General Topography*. Bucharest: University Press.
6. RIEGL, 2022. <http://www.riegl.com/>. [Online]
Available at: <http://www.riegl.com/nc/products/airborne-scanning/produktdetail/product/scanner/72/>
[Accessed 10 November 2022].
7. RIEGL, 2022. <http://www.riegl.com/>. [Online]
Available at:
http://www.riegl.com/uploads/tx_pxpriegldownloads/RiACQUIRE_datasheet_2022-09-01.pdf
[Accessed 10 November 2022].
8. Tal, D. & Altschuld, J., 2022. *Photogrammetry. In: Drone Technology in Architecture, engineering and construction: A strategic guide to unmanned aerial vehicle operation and implementation*. s.l.:John Wiley & Sons.
9. TerraSolid, 2022. terrasolid.com. [Online]
Available at: <https://terrasolid.com/>
[Accessed 10 November 2022].
10. TerraSolid, 2022. terrasolid.com. [Online]
Available at: <https://terrasolid.com/products/terramodeler/>
[Accessed 10 November 2022].
11. Torleàrrd, A., 1986. *Some Photogrammetric Experiments With Digital Image Processing. The Photogrammetric Record, Volume 12*, pp. 175-196.