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LIDAR SCANNING OF THE TERRITORY OF THE REPUBLIC OF NORTH MACEDONIA

The fast pace of modern life creates a need to apply new technologies and methods that would help us achieve our goals in a short period of time in any field of life. This is also required in the field of spatial data acquisition, i.e., the goal is to find a way to obtain accurate and detailed spatial data from the Earth's surface in a shorter period of time. In that direction, LiDAR technology is one of the most powerful and promising data acquisition technology, providing fast, precise and detailed spatial data for the Earth's surface.

The digital terrain model and the digital surface model generated by this technology are at a very high level of detail, thus makes this technology useful in various areas, primarily in crisis management, environmental protection, spatial planning, engineering geodesy, agriculture, defence and other areas where geospatial data are used.

Following the world trends, the Agency for Real Estate Cadastre has started a project that includes LiDAR scanning of the entire territory of the Republic of North Macedonia, building institutional capacities for the process of controlling LiDAR data and their archiving, as well as creating a LiDAR portal to distribute the LiDAR products to the all interested users.

Keywords: LiDAR, Point Cloud, Digital Terrain Model, Digital Surface Model

1. LIDAR TECHNOLOGY

1.1 BASIC CONCEPTS AND DEFINITIONS

LiDAR or Light detection and ranging (LiDAR) is an active remote sensing technology that uses electromagnetic energy in the optical range to detect an object (target), determine the distance between the target and the instrument (range), and deduce the physical properties of the object based on the interaction of the radiation with the target through phenomena such as scattering, absorption, reflection, and fluorescence.

The basic components of the LiDAR system are:

- LiDAR scanner,
- GPS receiver,
- IMU – Inertial Measurement Unit,
- Computer and data warehouse.

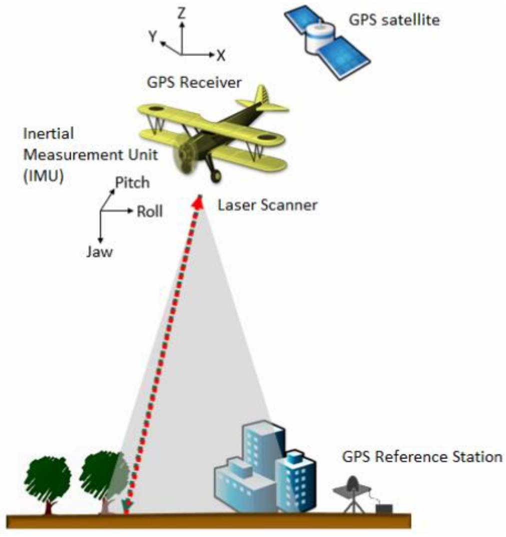

Figure 1. Components of the LiDAR system

The concept of this technology is based on accurate measurement of the time for which the laser beam is emitted from the corresponding module in the LiDAR system to the ground, then is reflected from the ground or from an object on the ground (vegetation, building, bridge, power line, etc.) and then returned to the sensor housed in the LiDAR system.

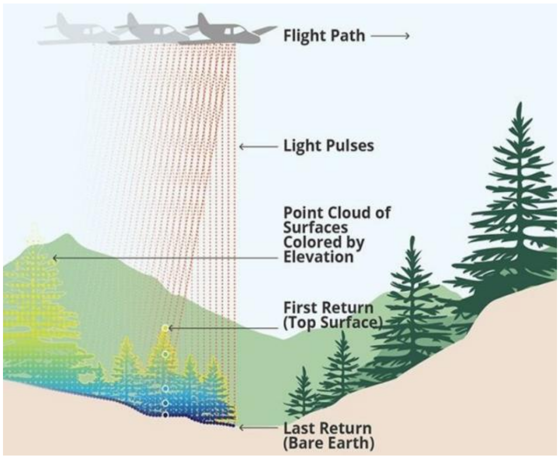

Figure 2. Basic concept of LiDAR technology

When the laser beam returns, it carries information about the object it has come in contact with, including distance and optical characteristics such as reflectivity.

A single emitted laser beam can be returned to the sensor as one or more returns. Each emitted laser pulse that encounters multiple reflective surfaces as it travels to the ground is divided into as many returns as there are reflective surfaces.

The first returned laser beam is the highest characteristic on the Earth's surface, such as a tree or the top of a building. The first return can also be from the ground and in that case only one return from the corresponding laser beam will be detected in the LiDAR system.

The multiple returns allow multiple objects to be detected at different altitudes within a single laser pulse. The middle return is used for vegetation analysis while the last return is used for terrain models of the ground.

The last return does not always have to be a return from the ground. For example, if the pulse hits a thick branch on its way to the ground, it does not actually reach the ground. In this case, the last return is not from the ground.

LiDAR has many advantages that make this technology attractive in the field of spatial data acquisition, some of those are:

- spatial data acquisition speed (around 500000 points per second),
- vertical data accuracy (+/- 10 cm),
- point density (minimum 2 points per m^2, but often 5 or more points per m^2),
- independence from the presence of vegetation to collect data of the structure of the terrain,
- independence from the period of the day when the data is collected,
- integration with other data sources (orthophoto images, vector data for parcels, buildings, roads, bridges, etc.).

1.2 LIDAR PRODUCTS

1.2.1 Point Cloud

Post-processed spatially organized LiDAR data is known as Point Cloud. The starting Point Cloud is a large collection of 3D points, which have defined X, Y and Z coordinates but can also contain attribute data for:

- Intensity,
- Number of returns,
- Return number,
- Class code according to the type of object from which the point is reflected,
- RGB value,
- GPS time,
- Scan angle,
- Scan direction.

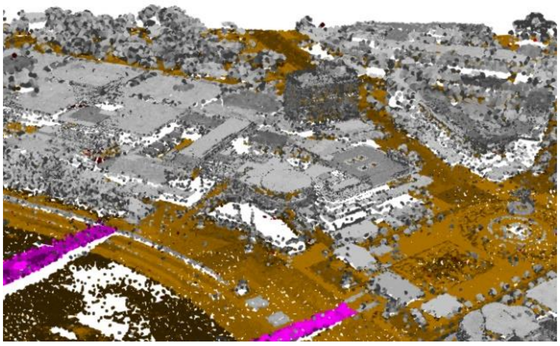

Figure 3. Point Cloud visualized by class and intensity (brown–ground points, pink–bridge points, grey–unclassified points)

1.2.2 DTM vs. DSM

LiDAR Point Cloud is commonly used as input for creating digital elevation models.
DTM (Digital Terrain Model) is a mathematically defined continuous surface in digital form that with a certain accuracy represents the terrain.
DSM (Digital Surface Model) is a mathematically defined continuous surface in digital form that with a certain accuracy represents the terrain along with natural and artificial objects located on the terrain.

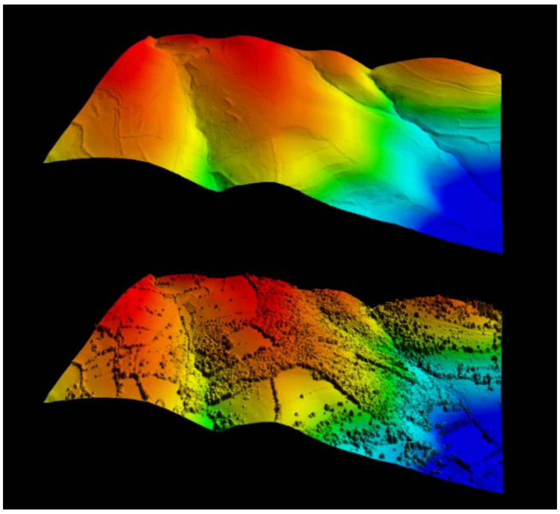

Figure 4. Digital Terrain Model vs. Digital Surface Model

1.3 APPLICATION OF LIDAR TECHNOLOGY

LiDAR technology can make a major contribution in various areas that need high-quality spatial data.

1.3.1 Engineering Geodesy and Civil Engineering

LiDAR provides a detailed view of objects of interest, identification of changes in relation to the planned and performed condition or condition recorded after a certain time. LiDAR products can also be used as a basis for designing and volume calculation.

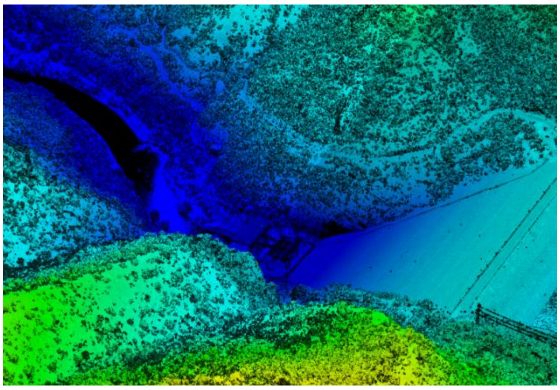

Figure 5. Point Cloud of Kozjak Dam

1.3.2 Spatial Planning

By applying the data from the LiDAR scanning and combining them with spatial data from other sources (orthophoto images, vector data for parcels, buildings, roads etc.) a 2D/3D spatial models can be created, which are an excellent basis for improving spatial planning, analysis of lighting, etc.

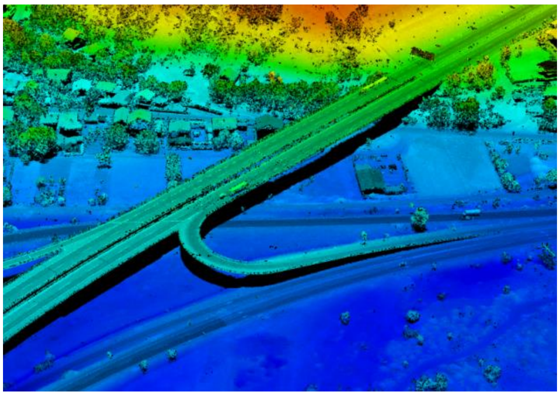

Figure 6. Point Cloud of Skopje - Northern Bypass

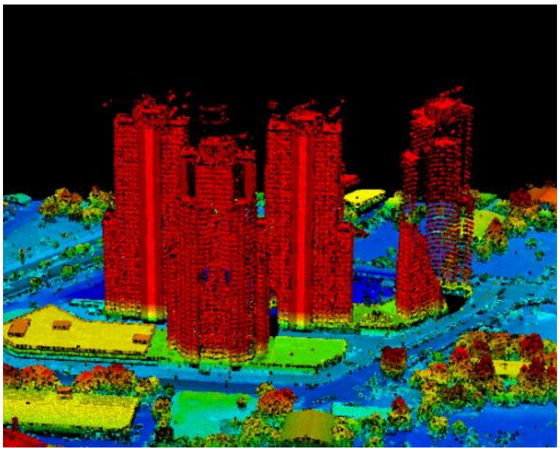

Figure 7. Point Cloud of Cevahir Towers

1.3.3 Forest and Environmental Management

LiDAR technology enables the detection of each tree, its height, volume, density, which is of great importance in forest management, classification of vegetation types and fire protection.

1.3.4 Geology

In areas with dense vegetation, it is almost impossible to accurately detect geological phenomena such as landslides. LiDAR technology can be used to assess impacts and movements in this type of areas.

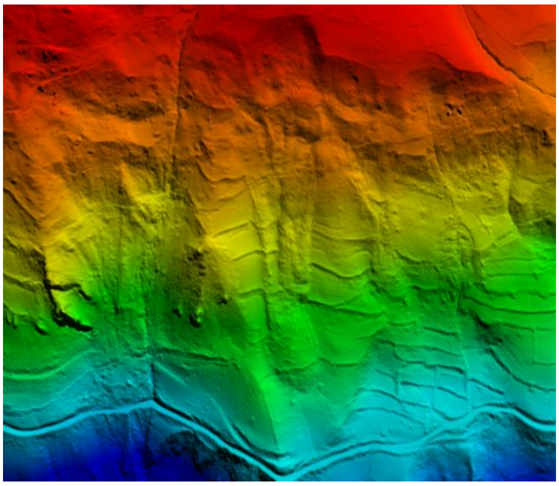

Figure 8. DTM of a landslide in Polog Region

1.3.5 Archaeology

In archaeological excavations, LiDAR technology can be applied in planning research actions, field studies and detailed site research. LiDAR data can detect debris of wall structures in the study area.

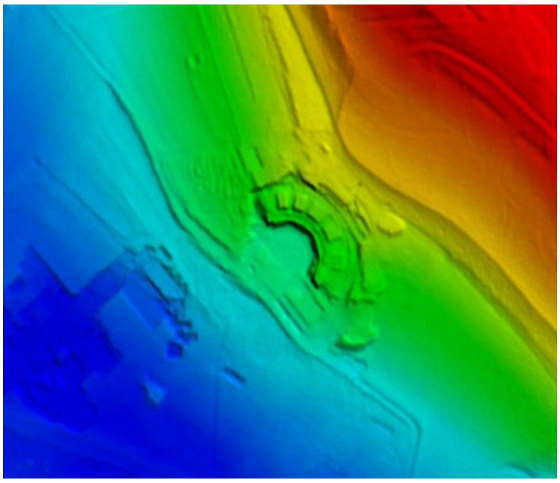

Figure 9. DTM of Skupi Archaeological Site

2. LIDAR PROJECT

The Norwegian Ministry of Foreign Affairs and the Norwegian Mapping Authority (Statens Kartverk) have concluded an agreement for financial aid for the Balkan countries (North Macedonia, Serbia, Bosnia and Herzegovina, Montenegro, Albania and Kosovo) with the goal of improving the access to updated geographic information and to basic registers, for the period October 2017 – October 2020. With this agreement, the Government of Norway, through the Norwegian Mapping Authority, supports the countries from the region in the process of obtaining updated geographic information in digital form, available via the Internet both to the public and the private sector, for the purpose of mitigating the effects of climate change. The grant agreement states that individual agreements on institutional cooperation will be concluded between the Norwegian Mapping Authority and each of the partner institutions in the region. Within this cooperation, the Agency for Real Estate Cadastre applied with the project "*LiDAR surveying of the territory of the Republic of Macedonia for the preparation of precise digital height models and other quantitative and qualitative analyses of the Earth's surface*".

For the purpose of implementing the project activities, the Agency for Real Estate Cadastre and the Norwegian Mapping Authority in March 2018 signed a cooperation agreement. The project activities include LiDAR scanning of the territory of the Republic of North Macedonia, building institutional capacities for the process of controlling the LiDAR data and their archiving, as well as creating a LiDAR portal for distribution of the LiDAR products to the end-users.

LiDAR scanning of the territory of the Republic of North Macedonia within the first phase of the project was carried out by the company MGGP Aero from Poland, based on a tripartite agreement signed with the Agency for Real Estate Cadastre and the Norwegian Mapping Authority in December 2018. Within the first phase of the LiDAR project, appropriate LiDAR products have been prepared for 11072 km^2 of the territory of the Republic of North Macedonia. That is 43% of the country. The territory covered by LiDAR scanning is divided into 14 blocks:

- Block 1, Block 4, Block 12, Block 13 and Block 14 – with point density 5ppm^2,

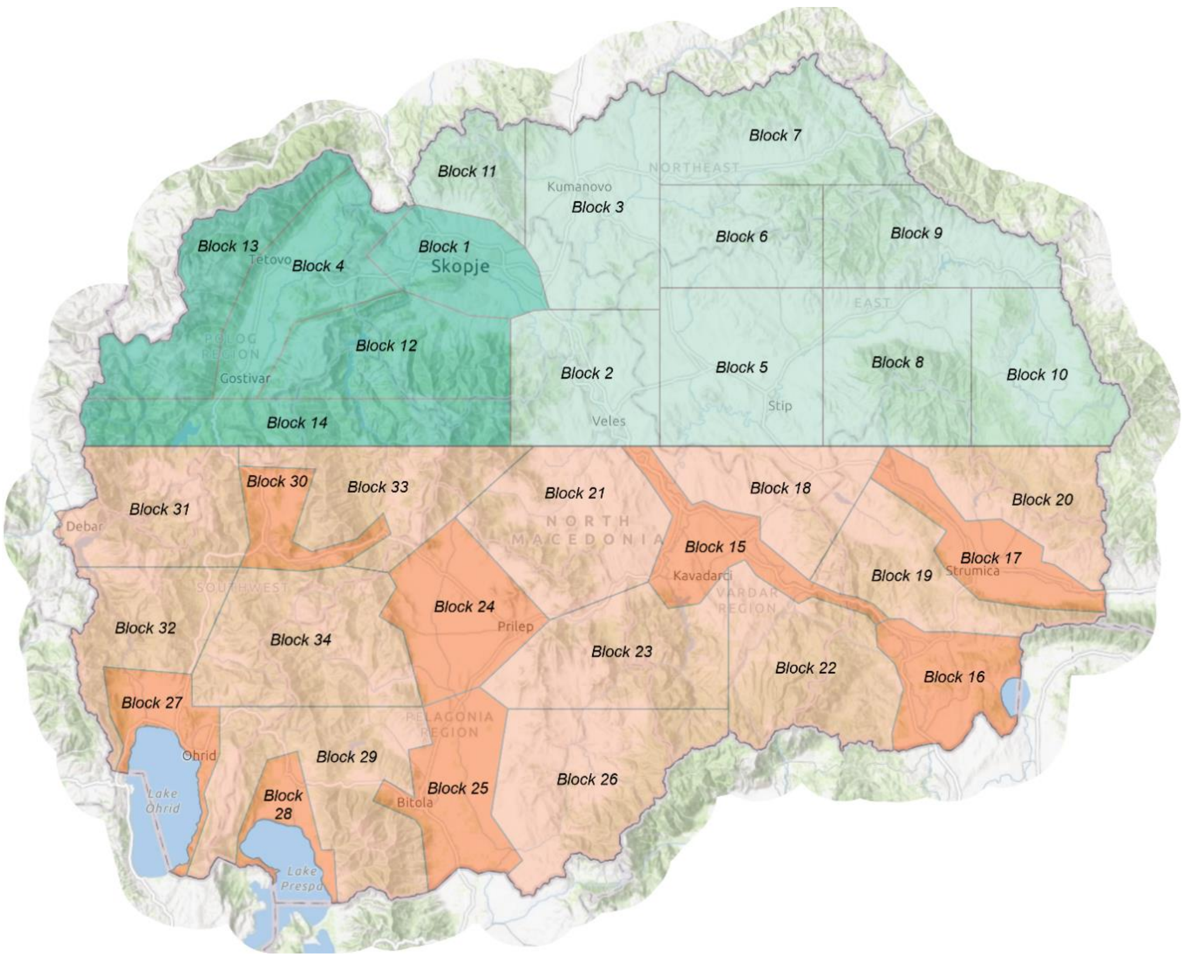

Figure 10. LiDAR project – division into blocks (green–first phase, orange–second phase)

- Block 2, Block 3, Block 5, Block 6, Block 7, Block 8, Block 9, Block 10 and Block 11 – with point density 2ppm^2.

In September 2020, the Agency for Real Estate Cadastre and the Norwegian Mapping Authority, have concluded an Annex to the Agreement on Institutional Cooperation regarding the LiDAR project in order to extend the project duration period by 31.12.2021, as well as expansion of the budget frame. In October 2020, a tripartite agreement was signed for the second phase of the project, between the Norwegian Mapping Authority, the Agency for Real Estate Cadastre and the company Primul Meridian from Romania. Within the second phase of the LiDAR project, the territory of the Republic of North Macedonia covered by LiDAR scanning is divided into 20 blocks:

- Block 15, Block 16, Block 17, Block 24, Block 25, Block 27, Block 28 and Block 30 – with point density 5ppm^2,
- Block 18, Block 19, Block 20, Block 21, Block 22, Block 23, Block 28, Block 29, Block 31, Block 32, Block 33 and Block 34 – with point density 2ppm^2.

3. LIDAR PORTAL

In order to offer a simple and fast way to provide LiDAR data to all interested users, a LiDAR portal has been created as a technical solution for distributing the data obtained with the LiDAR scanning of the terrain.

Figure 11. Home page of LiDAR portal

Customers have the ability to choose one of three offered options to specify the desired area for purchasing LiDAR products. The area for purchasing may be specified by:

- selected frame/s at a scale of 1:1000,
- uploaded polygon in shp–format into the LiDAR portal,
- drawn polygon directly into the LiDAR portal.

For the specified area, the customer has the ability to choose a type of LiDAR product that is interested in: LiDAR Point Cloud, DTM or DSM.

Figure 12. Drawn polygon as input for purchasing LiDAR products

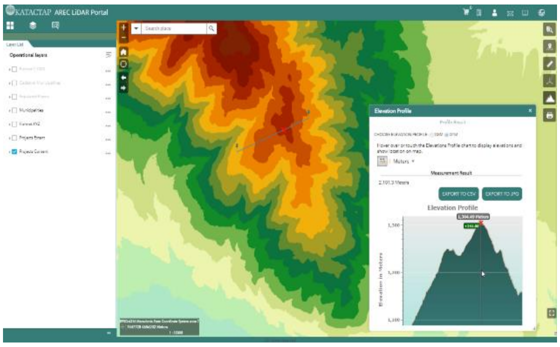

Figure 13. Elevation profile in LiDAR portal

LiDAR portal offers various possibilities for visualization and analysis of LiDAR data, tools for measuring distance and area, as well as tools for creating elevation profile of a digital terrain model or digital surface model.

4. CONCLUSION

LiDAR technology opens a new era in the field of spatial data acquisition, providing fast, accurate and detailed spatial data. This technology, as well as the technology for processing the data obtained from LiDAR scanning and for creating new products, are becoming more accessible and more advanced day by day and give a great contribution in all areas that need quality spatial data. All interested users now are able to take advantage of this powerful spatial data provided through the LiDAR project of the Agency for Real Estate Cadastre.

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