PRE-PROCESSING AND POST-PRECESSING LIDAR DATA

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Abstract
The present paper is aimed at establishing whether and to what extent LiDAR technology proves useful and what precision can be obtained with this type of data. The methodology was applied on a series of LiDAR surveys from the area of United States of America, State of California, area of Los Osos, that were closely analyzed in the pre-processing stage from the viewpoint of their accuracy by means of suggestive statistical indicators.
In the post-processing stage, it was used two software packages – QTRender 800 and Global Mapper - capable of processing this kind of LiDAR surveys in order to obtain a highly precise digital terrain model (DTM) and other products.

Keywords: LiDAR technology, accuracy, software, DTM.

INTRODUCTION
The surveying of all types of land use actually allows us to get to know our territorial fund, this being achieved in the past through field works that assumed time-consuming and tiresome determinations, travels and descriptions, especially in steep land conditions.

Lately, was attempted and mostly achieved to use modern means to fulfill this objective, means that are reflected in modern technologies, such as: GPS-based positioning or deriving qualitative geo-topographic data through airborne and satellite remote sensing.

Nowadays, these techniques and technologies are covered by the geomatics, to which it can be attached several definitions and whose objective is to get to know a part of the Earth’s surface from two viewpoints: its position in a reference system and its mapping/translation into plans [2].

The base concept is to determine the distance from the airborne platform to the monitored Earth’s surface, the off-nadir scan angle, the aircraft’s position in its reference system and, subsequent to the pre-processing stage, the coordinates of the points reflected off the ground or by other objects that the laser pulses encounter, the surveyed points being known as point cloud (Figure 1), [4].

The laser scanning LiDAR technology (Light Detection and Ranging) falls within this science and consists of a laser scanning technique combined with a highly accurate GPS-IMU (Inertial Measurement Unit) system mounted on an airborne platform [1].

Fig. 1. Operating Mode in Airborne Laser Scanning (Birjaru, 2011)
This paper’s objective is based/centred on the question whether and to what extent we should use LiDAR technology, and the goals to be fulfilled are:

- getting acquainted with the modern 3D laser scanning LiDAR technology both theoretically, as well as from the viewpoint of its general uses;
- establish what precision can be obtained with this type of data;
- obtaining a highly accurate digital elevation model (DEM) and other specific topographic products;
- mentioning the fields that could integrate LiDAR technology or where this technology could serve some indirect purposes.

MATERIALS AND METHODS

The data used in the present study were received from the company Watershed Sciences Inc (WSI) that collected them for „PACIFIC GAZ AND ELECTRIC COMPANY”, on request by the latter. The data were collected in the United States of America, State of California, area of Los Osos, because such data being difficult to obtain in Romania.

The LiDAR data were collected between March 17th and May 31st, 2011, and the area of interest was of ≈675 km² (166,696 acres), subsequently extended by including a buffer area of 100m to ensure full coverage and adequate point density close to the one required (8 points/sq.m.). The final area was of ≈688 km² (169,968 acres) (Figure 2).

The methods that were applied to perform the analysis and present the results are those commonly used and especially materialized in the methodology used for the majority of the works. At the core of this methodology lies the direct observations performed and obtained on the occasion of the flight and data processing. We equally made use of indirect observations derived from additional work stages dependent on collateral factors.

The methods used during the present study are: the direct comparison method and the statistical method.

As a working methodology, terrestrial and aerial surveys were performed in Real Time Kinematic (RTK) mode at times when the Point Dilution Of Precision (the PDOP) was lower or equal to three and the number of active satellites on the Earth’s sky defining the satellite constellation at the moment of data collection was of minimum six. The terrestrial RTK surveys are used to assess the accuracy of the collected LiDAR data, while the aerial RTK surveys serve to determine the aircraft’s position during the release and receipt of the laser pulses (Figure 3).

Static surveys were also performed close to the flight area in order to link the terrestrial and aerial segments and be able to determine the coordinates of the surveyed point cloud in the pre-processing stage.

RESULTS AND DISCUSSIONS

ACCURACY ASSESSMENT

The relative accuracy refers to the internal consistency of the dataset, more precisely to the ability to place a laser point in the same location over multiple flight lines, GPS conditions or aircraft altitude. This indicator of LiDAR surveys can be understood as the divergence between points from different flight lines over the overlapping area [7]. The system is deemed well calibrated when the divergence between the ground levels of the same point from the overlapping area is less than 10 cm (Figure 4).
Another indicator of the LiDAR surveys is absolute accuracy defined as a function dependent on two other indicators - laser noise and relative accuracy [7].

Prior to assessing absolute accuracy, we used a number of noise filters and calibration procedures to minimize the effects of these contributions (laser noise and relative accuracy). 2482 RTK points were collected in the study area of Los Osos on hard-packed surfaces (that meet location requirements) distributed over multiple flight lines. To assess absolute accuracy, the coordinates of the 2482 RTK points were compared to those of the nearest laser points on the ground (Figure 5). The vertical accuracy of the LiDAR data is defined as standard deviation \( \sigma \) resulting from the divergence between the coordinates of the LiDAR points and those of the RTK surveyed points (Table 1).

Another indicator was used to draw statistical models of the vertical accuracy, namely the Root Mean Square Error – RMSE [9].

This RMSE can be computed only for areas void of vegetation, more precisely for clear, potentially topsoil stripped areas where points were surveyed with the RTK method.

The initial dataset with a point density higher than 8 points per square meter was then filtered to remove false or inaccurate points. Moreover, some types of surface area (for instance: dense vegetation, bare land, water, steep slopes) may return fewer pulses (with a lower density) than those issued initially (with an implicitly higher density).

The land cover classification was achieved both through automatic and manual modelling, while the supervised classification revealed that automatic modelling was not entirely accurate since the derived model was not compliant with the ground truth at the time of the data collection.

Following the processing of the collected data, we concluded that the purpose of this study was achieved with a resolution of 8.28 points/m\(^2\) and a vertical accuracy of 2.8 cm (Figure 6).

![Fig. 4. Distribution of Relative Accuracies in the Study Area of Los Osos per Flight Line, non Slope-adjusted](image)

![Fig. 5. Absolute Accuracy - Divergence between Laser Points and RTK Surveyed Points](image)

![Table 1 Absolute Accuracy - Divergence between Laser Points and RTK Surveyed Points](image)

![Fig. 6. Distribution Map for Unclassified Points (up) and Distribution Map for Ground Classified Points (down)](image)
DATA POST-PROCESSING

The software packages capable of processing this type of data can be classified according to the possibilities they offer into two categories [5]:
1. software for the visualization of LiDAR datasets (viewers);
2. software that allows users both to visualize LiDAR data and to derive specific topographic products (digital elevation models, profiles and other topo-cadastral pieces).

We should mention that for the purpose of the present study we did not consider the entire area which served for the collection of the LiDAR data since the number of points surveyed on this area is of approximately 5.4 billion points, and current software can only process approximately 100 million points. For this reason, we chose an area that would serve the targeted results, namely to obtain a highly accurate digital elevation model based on a number of 98,437,917 points surveyed on a 7.939 km² area.

QTREADER SOFTWARE

After selecting the file that we want to visualize, the software loads the model that can be visualized in a few seconds or in several dozen of minutes, according to its size. The time needed to load the model is directly dependent on the number of points that make up above mentioned model. In our case, the time needed to open the model was of 14.5 min for a number of 98,437,917 points (the opened file is 2.8 GB).

This software allows users to rotate the model, zoom it to a particular constituent point, or change colours according to point ground level, as well as other operations for the detailed visualization of the model (Figure 7).

Mention must be made on the fact that this software allows its users to read the coordinates of targeted points in the used projection system (Projection system NAD83 - North American Datum 1983/UTM zone 10N, defined by NAD83 coordinate system and the GRS 80 ellipsoid), (Figure 8).

The software also allows drawing a grid for the inserted model if needed by accessing the sequence Analysis-Generate Grid Lines and selecting the desired settings in the prompt window. The grid complying with the selected settings shall be displayed after clicking the Ok button (Figure 9).
GLOBAL MAPPER VERSION 13 SOFTWARE

Global Mapper is more than a viewer that allows visualizing tri-dimensional models. It is a software which allows users to perform several operations, such as: calculation of the surface area, river basin delineation, spectral analyses, generation of DEMs, contour lines or profiles for the study areas, as well as a series of other operations that can serve different purposes.

The file containing the data for the generation of the highly accurate digital elevation model can be opened with the sequence File-Open Data File(s) or by left-clicking the Open Your Own Data Files button which prompts when the software is opened. After selecting the file and clicking the Open button, a new window prompts (LiDAR Load Options) with two options: generating a point cloud or directly creating a digital elevation model. Of these two options, we chose the first one. The software offers the possibility to select the points in relation to their characteristics that are closely connected to the pre-processing stage when the points were classified according to their sensor return time. For the purpose of the present study, we inserted the points that were classified as soil by selecting this option (Figure 10, Figure 11).

The digital elevation model to be derived based on this cloud point was obtained by clicking the Open Control Center button. This opens the window Overlay Control Center which contains the inserted point layer and allows the user to read their number according to the selected inserting options (Figure 12).

It is important to keep in mind that the model maintains the accuracy of the input data for which reason one can state that the resulting digital model is highly accurate being based on highly accurate input data both altimetrically and planimetrically [8].
The digital elevation model allowed us to generate the corresponding contour lines with the sequence File-Generate Contours (Figure 13).

![Fig. 13. Contour Lines Derived from the Digital Elevation Model](image)

The software also offers the possibility of deriving profiles for the study areas based on the digital elevation model, and this was achieved by clicking the 3D Path Profile/Line of Sight Tool button on the upper toolbar (Figure 14).

![Fig. 14. Longitudinal Profile of a Road from the Study Area](image)

Another useful function of this software is the possibility to generate the watershed. This function meets the needs of other disciplines as well (river basin management and planning, torrent study) since the derived information can help identifying areas subject to risks of floods, land slides or torrents (Figure 15).

![Fig. 15. Watershed Derived for the Study Area](image)

CONCLUSIONS

A series of general findings and future concerns can be derived in relation to the performed activities and this can be resumed as follows:

1. The 3D laser scanning LiDAR technology is a component of the new science called geomatics.

2. LiDAR technology is an active remote sensing system based on the release of a weak scattering laser pulse and the receipt by the sensor of the radiation reflected by the scanned surface area; the result is a ‘cloud’ consisting of thousands of 3D positioned points.

3. The main advantage of this system is the fact that the data collection, storage and processing process is fully automated due to the use of specialized software which allows users to obtain coordinates with a horizontal accuracy (x, y) of less than 10 cm and a vertical accuracy of 2.8 cm.

4. The ability of the laser pulse to pierce through forest canopy all the way to the ground is the essential characteristic of this system.

5. By using software packages capable of processing this kind of data we managed to obtain highly accurate digital model of the ground truth, its high accuracy being due to the input data.

A series of different other products can be obtained based on the digital elevation model (contour line maps of the study area, profiles, watersheds, etc.), as well as a series of indirect information such as tree height or building height which allows for predictions on areas potentially prone to floods, landslides or torrents.

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