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COMBINING LIDAR AND PHOTOGRAMMETRIC DATA FOR OBTAINING A DIGITAL TERRAIN MODEL

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Abstract- Everyone today recognizes that photogrammetry has been the leader among the remote sensing techniques and now LIDAR has carved a niche for itself. Because there are two strong remote sensing options and also their final products are similar in quality, this study is concerned with the integration of photogrammetric and LiDAR data to achieve a more complete surface description and Digital Terrain Model. The main objectives of this work include the combination of data acquired by photogrammetric techniques and LiDAR. It also considers the development of a method for a better integration of models. Using an irregular grid points were made interpolations of the two models and have done profiles on the border between models. Finally, spline surfaces were deterninated and were associated with the initial models in order to improve the integrated model.

Keywords: *LiDAR, photogrammetry, digital terrain model, accuracy*

I. INTRODUCTION

Laser scanning and digital photogrammetry are different approaches that are often used to obtain the same result – a 3D model of a real-world scene [1].Digital terrain models (DTMs) have been used in geoscience applications since the 1950. Since then they have become a major constituent of geographical information processing. They provide a basis for a great number of applications in the earth of the engineering sciences. Flexibility and adaptability to given problems are fundamental objectives of a digital terrain modeling system, therefore the choice of data source and terrain data sampling techniques is critical for the quality of the resulting DTM.

Both LiDAR and photogrammetry are mapping techniques and the different methods used result in differences in accuracy, range, speed, cost and suitable application areas[1]. It is necessary to explain and understand the difference between LiDAR and photogrammetry in order to emphasize the purpose of this study.

Digital photogrammetry defines shape, size and position of objects using images taken from different points of view[2].The overlap of the air photo permits stereo viewing, allowing positions and elevations to be calculated mathematically from Ground Control Points (GCP). The standard procedure to generate DEM's are based on fundamentel steps which consist in internal orientation, external orientation and point extraction.

LiDAR, on the other hand, operates by scanning with a laser rangefinder, resulting in datasets of millions of random, individuals points on above-ground features[3]. By measuring the direction the laser was fired in and the time it takes for the light to return, the scanner can determinate the 3D location of the surface that the laser reflected off. By firing off a large number of pulses in a regular pattern the scanner is able to create a Digital Terrain Model of the scene. Having these two strong remote sensing options, there is the question "Should we choose LiDAR or photogrammetry for obtaing a Digital Terrain Model?" In order to find the answer, in this study , having the DTM obtained from photogrammetric data, we proposed improvements in forest areas by processing LiDAR data.

Combining the two technologies to obtain a good integration of the models is one of the main objectives with the creation of the spline surfaces and association of them with the initial models. During the study it was emphazized the fact that each of these technology has its own strengths and weeaknesses, but the integration of the models generates a better digital terrain model for the study area.

II. STUDY AREA AND DATA

The study area (Figure 1) is located in the Olt valley, in Romania where a plot of 144$m^2$was established according with a general protocol. Information about plot used for the study is displayed in Table 1.

Table 1.LiDAR data information about plot

Area	Exposition (grad)	Slope (degree)	Altitude (m)	Area (m^2)	Inventory data
Olt Valley	362	13	1250	12x12	2011

For the study were used both photogrammetric data with a vertical accuracy of 0.7-1 m and LiDAR data for which vertical accuracy was about 0.1-0.3 m.

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To obtain the photogrammetric data it was used a photogrammetric camera Leica ADS 80 and laser data was acquired with a fullwave RIEGL LMS-Q560 scanner.

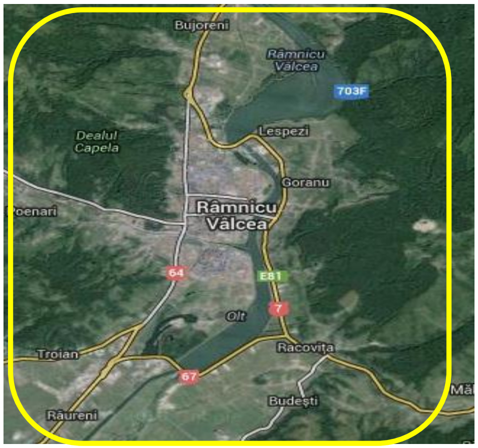

Figure 1. Study area

Acquisition parameters are summarized in Table 2. Echoes were extracted from the binary acquisition files and georeferenced with the RIEGL software suite.

Table 2. Laser data

Flight parameters	***Olt Valley***
Flight year	2011
Scanner	RIEGL LMS-Q560
Pulse repetition rate (kHz)	120
Scan Frequency(Hz)	77.3
Half scan angle	30
Flight height (m)	1172 to 1490
Laser footprint (m)	0.3
Theoretical point spacing (m)	0.6
Flight strip overlap (%)	50

The study was based on the fact that having the digital terrain model from photogrammetric data it was necessary to have more accurate information in forested areas by using LiDAR data, so the border for the models can be seen in Figure 2.

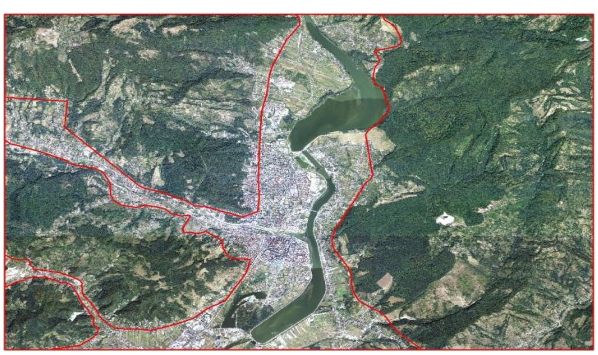

Figure 2.The border between models

III. INTEGRATION OF THE DIGITAL TERRAIN MODELS

In most of the papers, the same area is covered by different sensors, and is extracted a better digital terrain model than the initial ones. In this paper, because of the considerations mentioned in the introduction, a part of the area is covered with the LiDAR sensor, and for the other part is generated a digital terrain model from photogrammetric data.

Precisions of the digital models are different, so there will be some difficulties in the process of combination. For a better result and precision, will be used some GCPs. A quick check over the digital elevation models showed that the differences between them are in the interval of 20 cm – and 130 cm. Because of that, the locations of the GCPs will be very important, because they will have to cover the most of variations, that with a number of GCPs that will keep this method with good costs.

In this way, on the line of intersection of the areas (defined on the major roads), will be calculated the differences between DEMs, and then will make profiles to see how it varies. It was considered that on the major roads, the precisions of both DEMs are better that in other areas and have small variations in time (time diference between the flights is about one and a half years).

Figure 3. Delimitation of the areas

On the orto was identifiend points along the major roads at every 500 m to 1.000 m. Using the elevation differences from every point were generated such profile like in Figure 3. To minimize the number of the GCP and the differences, for every profile was generated a curve using spline interpolation, and the points used to define the curve are the feature locations of GCP (8 in the case shown in the Figure 6). This process will be done for entire limit. Beside the intersection lines, another GCPs have to cover the hole area, to ensure that entire surfaces will have in the end the same references in height and approximate the same precision. In this way, the DMTs can be mosaicated to obtain one final digital terrain model.

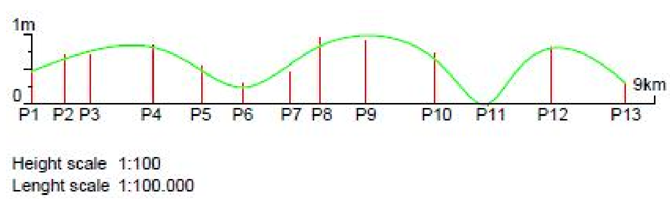

Figure 4. Longitudinal profile along the east border between the two areas

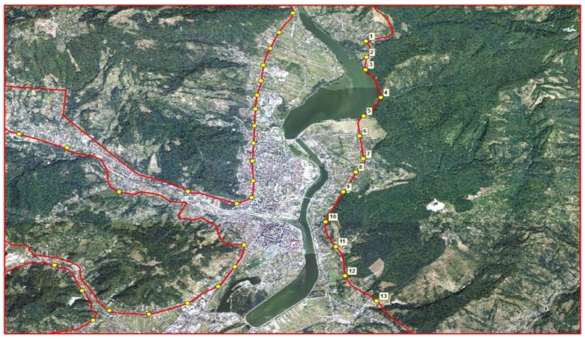

Figure 5. Borders between two DEMs and points along them used to built longitudinal profiles

When the analysis described earlier is done, we can go in the field to place the GCP and to measure them. For that were used 8 GNSS receivers, and the measures were post processed in the office for a better precision. Besides the projected points to be measured, a set of 5-7 points will be calculated for a later on check of this method.

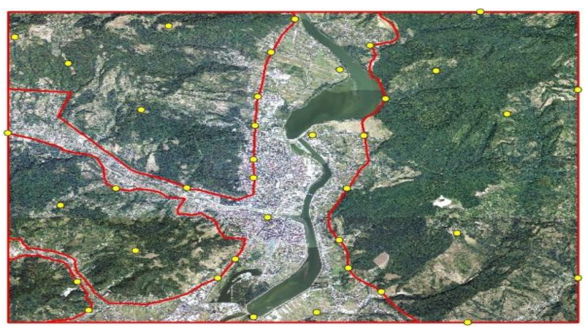

Figure 6. GCP used to generate spline surfaces of the differences

Now, for the both DTMs, in every GCP will be calculated the difference between model's height and GCP's height. Based on this elevation differences, using spline interpolation, will be generated two surfaces. Removing that values from existing DTMs, they will be corrected using the GCP values.

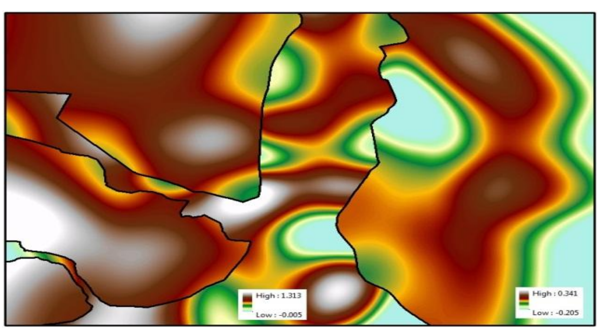

Figure 7. Spline interpolated surfaces based on the differences between heights of DTM and GCP

IV. RESULTS AND DISCUSSIONS

After the correction surfaces were used to bring the two DTMs in the same height reference system and improve the precision especially to the one obtained by fotogrammetric correlation, we should mosaic them at intersection border. But first, will verify the values of the resulting surfaces using 5 GCP that weren't used in the process described earlier.

Table 3.

	ZF Before (m)	ZL Before (m)	ZF After (m)	ZL After (m)	Z GNSS (m)
1	242.982	242.116	241.844	241.886	241.856
2	237.726	236.551	337.037	336.992	337.011
3	266.718	266.162	266.190	266.126	266.112
4	281.335	280.686	280.801	280.807	280.740
5	265.732	264.859	264.702	264.696	264.685

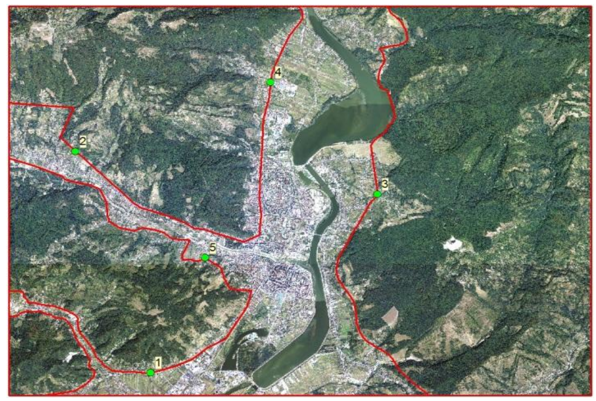

Figure 8. Distribution of GCP used to verify the new DTMs

As we can see, height diferences between DTMs after the processing are within 10 cm. Now we can mosaic them using the blend operator, and the output cell value of the overlapping areas will be a horizontally weighted calculation of the values of the cells in the overlapping area. Overlaping area will be along the red line between the two areas, with a width of 3 meters, and in this way, almost all common area will overlap the major roads.

V. CONCLUSIONS

As shown in the before chapter, it was managed to combine two DTMs by different precision. Using such a method, in general, it results a digital elevation model that has the precision equal with the one of the least precise model.

But, using the GCPs, distribuited in such way that all relative and absolute differences between the two digital elevation models were taken into consideration, the two models where brought into the same reference in heights. Even better, the precision was improved, and that could be observed in Table 3.

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