TERRESTRIAL LASER SCANNING OF THE HYDROTECHNICAL OBJECTIVES IN HYDROGRAPHIC SPACE DOBROGEA - LITORAL

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Abstract: *Terrestrial laser scanning is a new geodetic technique that allows fully automatic measurement of the geometry of a structure without a reflective environment, with high precision and high speed. The measurement result is represented by a lot of points, called as "point cloud" in the literature. This article presents an important step in the studies related to the "**Flood hazard maps and plan for prevention, protection and reduction of flood effects in hydrographic space Dobrogea - Litoral",** stage where terrestrial laser scanning technology is used to complement The Digital Model of Terrain obtained from measurements collected using LIDAR technology.*

Keywords*: terrestrial laser scanning, hazard maps, LIDAR technology*

1. Introduction

The project „**Flood hazard maps and plan for prevention, protection and reduction of flood effects in hydrographic space Dobrogea - Litoral**" is a project financed by the Cohesion Fund and the State Budget through the Sectoral Operational Environment Programme - Priority axis 5, key area of intervention 1, flood defense.

Through the project implementation has been followed: modernization of flood management on the components of prevention, protection and mitigation of their effects in the sense of national and European legislation.

Develop hazard maps and flood risk maps in the Dobrogea Litoral basin involves a variety of tasks which include achieving digital terrain model using LIDAR technology (Light Detecting And Ranging), this model being completed for specific areas of interest with information from terrestrial laser scanning.

It is obvious that the airborne acquisition of 3D models of objects in the environment does not provide the geometry of objects in detail. Therefore, in areas where data acquisition using aerial laser scanning technology (LIDAR) did not meet the accuracy or justify the cost, terrestrial laser scanning technology proves to be the optimal solution.

Complete solution with digital terrain model using information from terrestrial laser scanning allows an overview of the objectives under investigation and also the possibility of analyzing them in detail because after processing the data obtained through terrestrial laser scanning technique it can be obtain a 3D textured and polygonal model that is not just a virtual reproduction necessary for visualization and exploitation, but can be used to extract information regard size, shape and texture of the scanned object.

2. Description of the stages of data acquisition

A fully digital terrain model can be obtained only by unifying data obtained by the two techniques: LIDAR and terrestrial laser scanning. Therefore, we can say that terrestrial laser scanning is used to define / redefine coarse geometry models taken by airborne,scanning for land mapping purposes.

For hydrographic space Dobrogea – Litoral the engineering objectives were selected and validated by common accord with modeling experts team. Following objectives have been nominated (representative art works, historical and architectural monuments or representative hydro buildings):

Railway Bridge Targusor (3 spans), km 33+100, railway line Medgidia - Tulcea;
Railway Bridge Targusor (5 spans), km 37+ 300, railway line Medgidia - Tulcea;
Railway Bridge BAIA (2 spans) – km 85 +860, railway line Medgidia - Tulcea;
Railway Bridge COGEALAC (1 span) – km 52 + 100 railway line Medgidia - Tulcea;
Railway Bridge + Viaduct CASIAN, railway line Medgidia - Tulcea;

Laser scanning technology used for this work belongs to the category static laser scanning.Static laser scanning is defined if the scanner is installed in a fixed position during data acquisition. Advantages of this method are found in high precision of the results and in relatively high density of points. Laser scanners are still seen as the terrestrial laser scanners, but there is no clear delimitation between these two notions.

At terrestrial laser scanning for engineering objectives from hydrographic space Dobrogea - Litoral, we used a Leica ScanStation 2 type, from the endowment of the Faculty of Geodesy Bucharest. The features of this equipment represents the warranty for the quality of measurement results. These features, extracted from the Technical Specifications of equipment are presented in the table below.

Table 1 - Characteristics of scanning system ScanStation 2

Scanner/ criteria		**Leica ScanStation 2**
Laser class		3R
Laser spot diameter (mm to m)		4 mm at 50 m
Scanning method		*Time-of-flight*
Average collection rate (points / s)		30000
Vertical field of view [°]		270°
Horizontal field of view [°]		360°
Precision distance measurement (mm to m)		4 mm at 50 m
Distance range [m]		min 0.1 m, max 300 m
Scan speed [pts/sec]		≤ 50000
Angular resolution [°]	V	0,0023
	H	0,0023
3D Scanning accuracy		**6mm / 50m**
Camera (single image pixel resolution)		integrated
Tilting sensor		compensator
The manufacturer also has processing software?		Yes, Cyclone
The maximum density scan (mm / m)		1.2 mm at 200 m

Size (LxWxH)	265 mm x 370 mm x 510 mm
Weight (kg)	18.5 kg

The terrestrial laser scanning project was divided into five major stages, namely:

- measurements design;
- determining the coordinates of the points of constraint (scanning stations / points of orientation);
- data acquisition (terrestrial laser scanning itself);
- primary processing of data;
- data visualization.

Since the design of terrestrial laser scanning measurements was taken into consideration that each engineering objective to be "framed" correctly and as well as possible to highlight the technical features useful for obtaining a 3D model as expressive and that help to determine those geometric elements that lead to a proper hydrologic and hydraulic modeling.

Measurements were performed with total station LEICA BUILDER 300RM type, from the Faculty of Geodesy Bucharest, between 11 - 07/14/2012.

For each construction objectiv were designed and have determined a number of constraint points (scanning stations) fulfilling criteria mentioned above:

In order for terrestrial scan results to be integrated into the digital terrain model, the orientation (registration) of points clouds taken from different stations in a single scan reference system (projection system Streografic 1970, respectively ETRS 89 and the normal heights system with "0" fundamental point Black Sea 1975) requires identification of similar points from adjacent stations. These points, materialized in the field and previously determined (as a position) were marked with a "targets-of-sight" Leica type:

Figure 1 - Points marked with "targets of sight"

Determination of coordinates and heights of the constraint points (tie points) was performed before laser scanning operations, using conventional technology (total stations) and with reference to points from bridging and survey geodetic network and quasi-geoid model, determined in an earlier stage. At this stage we have used equipment (total stations) LEICA type, from the Faculty of Geodesy Bucharest.

As a measuring method, was used the method of polar coordinates (double), given that they were identified points from RGIR near the objectives to be scanned.

This situation has allowed the direct determination, on the ground, of constraint points coordinates, using special programs of the total station.

For each construction objectiv were designed and have determined a number of constraint points (scanning stations) fulfilling criteria mentioned above:

1. Railway Bridge Targusor (3 spans), km 33+100, railway line Medgidia - Tulcea:
   ☞ 3 scanning stations;


Figure 2 – Railway Bridge Targusor

2. Railway Bridge Targusor (5 spans), km 37+ 300, railway line Medgidia - Tulcea:
   ☞ 6 scanning stations;


Figure 3 – Railway Bridge Targusor

3. Railway Bridge BAIA (2 spans) – km 85 +860, railway line Medgidia - Tulcea:
   ☞ 3 scanning stations;


Figure 4 – Railway Bridge BAIA

4. Railway Bridge COGEALAC (1 span) – km 52 + 100 railway line Medgidia - Tulcea:

☞ 3 scanning stations;

Figure 5 – Railway Bridge COGEALAC

5. Railway Bridge and Viaduct CASIAN, railway line Medgidia - Tulcea:

☞ 8 scanning stations;

Figure 5 – Railway Bridge Pod and viaduct CASIAN

From a single station point can not achieve a full 3D representation. In order to avoid the obstacles that prevent complete data collection in a scene, it is recommended that the scan to execute from many station points.

Station point is chosen so that:

➢ to cover a larger portion from object and to prevent any not recovered;

➢ not to miss important details or be hidden areas;

➢ to establish large coverage between adjacent scanning stations to prevent systematic errors.

Recording an object under investigation by terrestrial laser scanning technology requires good knowledge about the equipment used and about the the scanning process. A very important attention should be given to phase of the acquisition of data. At present, in terrestrial laser scanners users community does not exist some standard procedures on data acquisition.

During data collection, special attention should be given to selection of parameters that characterize the operation. Be taken into account:

☞establishing visual field: the angle of horizontal and vertical scanning;

☞ coverage area of a scanning station;

☞ image resolution;

☞ measurement time (is a function of accuracy);

☞ laser beam diameter and deviation;

For scan operations to the works of art mentioned above, it was established initially a vertical resolution of 5 cm and horizontally of 5 cm to a maximum distance of about 15 to 30 m

Terrestrial Laser Scanning operations were performed in each station point belonging to each engineering objective. The scan result is represented by a considerable number of points, called generically point cloud.

Resulted points are characterized as position by coordinates x, y, z in a coordinate system specific to measuring system, with origin at the point from which scanning was performed.

In each station point was measured scanner height and heights for sighting targets, located in the constraint points (tie points), whose coordinates were determined previously.

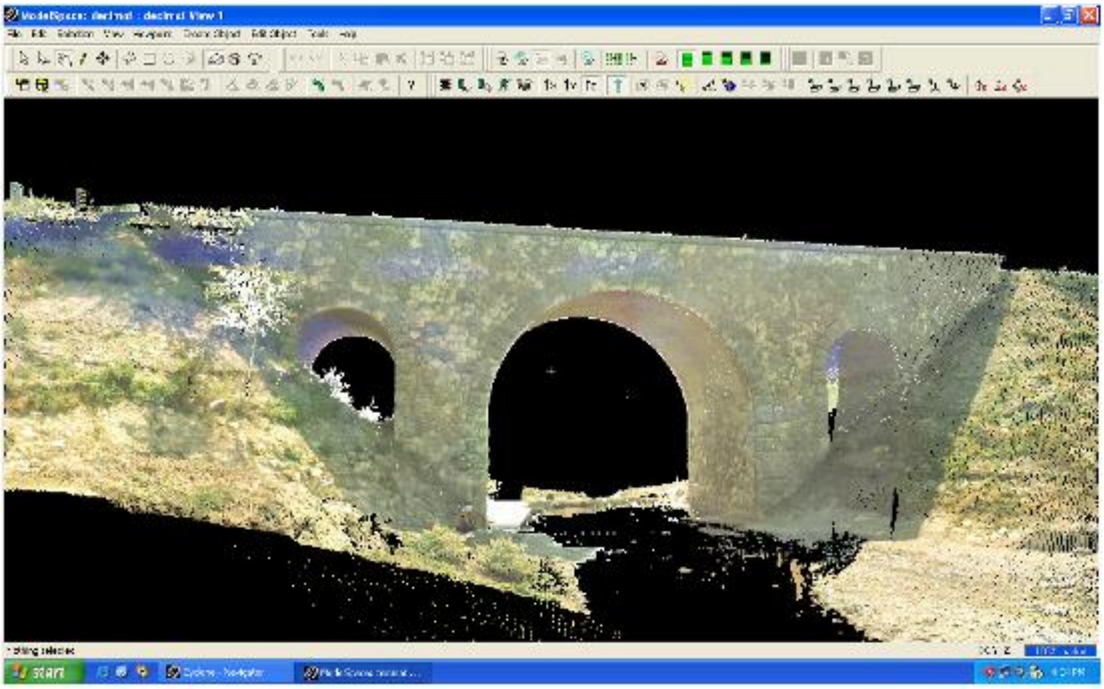

Figure 6 – TrueColor image

All scanning operations are "managed" by software component Cyclone of the scanning system. The selected scanning method was " TRAVERSE ".

Immediate results (primary) of the scan:

☞ 1:1 scale 3D geometric information (point cloud with unstructured information);

☞ Information on intensity (without information about the real color or texture);

☞ Representation of the measured object according to selected points grid (without characteristic points such as corners or end detail);`

☞ Scanning objectives, compared with their photographic images.

The images below are examples of "clouds of points" with unstructured information for each scanned objectiv, compared with their photographic images.

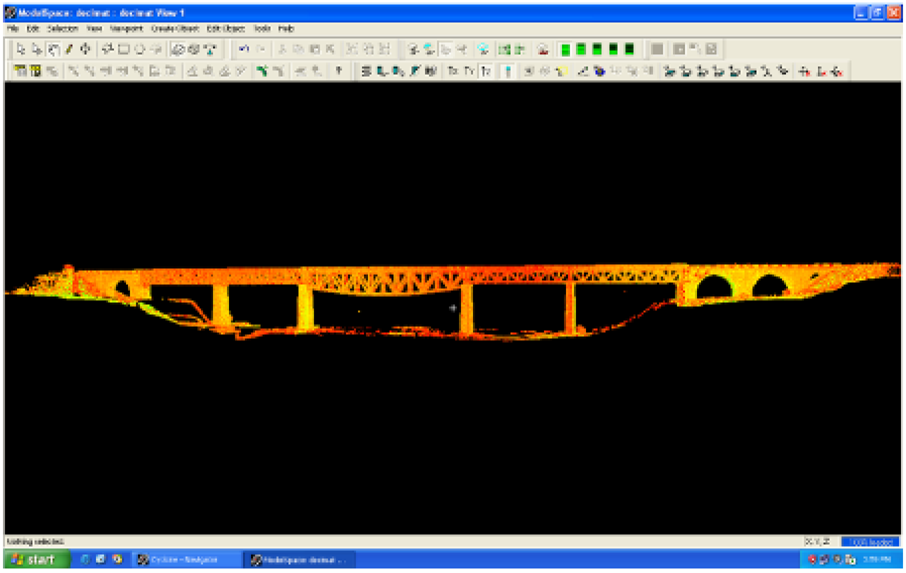

Figure 7 – Unfiltered point cloud

The final products of the scan are obtained by post-processing the information provided by "clouds of points" using appropriate software components. In general, these software components are provided by manufacturing companies, each bearing the imprint of that company differentiate itself significantly from one company to another.

In a final phase, we proceeded to the primary filtering data, meaning removing unwanted information from the cloud of points before creating the final product.

In laser scanning, unwanted data can result from various sources. For example, laser scanners can collect all the details that appear in the visual field, including pedestrians or vehicles, respectively details still insignificant (eg vegetation, portions of buildings, etc.). The laser scanner can collect false data reflected by the mirror surface (eg. drops of water).

After the primary filtration, have resulted data files for the 5 engineering objectives, files containing a considerable number of points which form 3D models of objectives that will be integrated in the terrain model obtained with LIDAR technology.

Table 2 - Content of related files of scanned objectives

Pts. No.	**Objectiv Name**	**Number of points**	
		Before filtering	**After filtering**
1	Bridge **Baia** – 2 spans	1535147	886413
2	Bridge **Casian** – 10 spans	7051694	5710462
3	Bridge **Cogealac** – 1 spans	1385100	866508
4	Bridge **Targusor** – 3 spans	1983438	972014
5	Bridge **Targusor** – 5 spans	4045822	2855996
TOTAL		**16001201**	**11291393**

3. Conclusions

In general, data acquisition is done in a very short time, which gives a crucial advantage of these systems compared to tacheometric surveys systems, for example. Post-processing of the data, however, can last longer, taking into account the huge amount of data that can be bought in a campaign scanning (eg can be tens of millions of points contained in a point cloud, which can fully characterize an object) and - not least - the ability of operators who participate in post-processing.

Terrestrial laser scanning is necessary only where the scanning aerial targets (LIDAR system) will give (collect) insufficient points to achieve a full 3D model (eg building objectives with slopes over 75 degrees). In those circumstances, after flight are resulting blank surfaces (gaps). These "gaps" may be supplemented by terrestrial laser scanning system.

In the case of earth dams (for example) that have embankments with small slopes, they will definitely result in the 3D model of flight LiDAR technology and - in this case - does not justify the use of terrestrial laser scanning.

In these cases, any "completions" can be achieved by determining the coordinates of the points of detail through easily applied technologies (eg GNSS - RTK and Total Station).

Terrestrial laser scanning is useful for targets with complex geometry, where the use of other technologies is not effective or possible.

Application of terrestrial laser scanning technology is only possible in normal atmospheric conditions and requires - additionally – the use of other measurement technologies, leading towards a full 3D model building objectives, model that can be integrated into the digital terrain model or digital model of surface reflectance.

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