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USE OF 3D TERRESTRIAL SCANNING (TLS) TECHNOLOGY IN THE FIELD OF HYDROTECHNICS

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Abstract. The purpose of this paper is to present the advantages of using terrestrial laser scanning technology (TLS) as a method of creating a 3D database and to create a 3D documentation for the Coșteiu Hydrotechnical Node. This ultra-modern technology is an innovation that has the advantage of acquiring a large volume of data in a short time. This technology together with UAV equipment has the advantage of obtaining a digital terrain model. Creating 3D models of heritage, archaeological objects and sites in their current state requires specialized equipment, knowledge, and has a strong methodology, capable of capturing and digitally models the geometric details and fine appearance of these sites. Digital recording, documentation and preservation are required because our heritage (natural, cultural or mixed) suffers because of different anthropic and/or natural actions (natural disasters, climate change and let's not forget about human negligence). Currently, 3D data represents a critical component for the permanent registration of the forms of important objects and sites, so that, at least in digital form, they can be transmitted to future generations. This has generated a large number of projects over the last decade, mainly led by research groups that have made very good quality models and complete digital models.
Keywords: Leica C10, Leica GS08, heritage, 3D model, UAV

1. INTRODUCTION

Since the early 2000s, terrestrial laser scanner (TLS) has evolved to provide accurate data and services. The technology is primarily used for the rapid acquisition of three-dimensional (3D) information. The objectives of cultural heritage, bridges, cars, plants, rock ridges, hydro technical nodes, highways, road accidents, and others, can be modeled, analyzed and stored in a database, and if necessary a 3D documentation on laser technology. LiDAR is currently the most successful data acquisition technique introduced in the last decade (Lemmens M., 2011).

UAV-based LiDAR studies are particularly attractive for use in locations where there are regular land surface changes (for example in high erosion environments, construction stability monitoring) and thus, if LiDAR archives or other DSM archives (Digital Surface Model) periodically requires updating (for example, agricultural areas) appear on a scale that is too thin to be accurately captured by other topographic sensors in the air or satellite. The ability of UAVs to fly nearby and with greater maneuverability than aircrafts with human crew will also provide finer spatial resolution in the resulting DSMs and digital terrain models (DTMs-Digital Terrain Model). In addition, through intelligent flight planning, UAV-LiDAR can achieve the collection of higher densities of point clouds over key areas (James et al. 2007).

As reference sources of reference in order to obtain a DEM using data with spatial accuracy at the ground level, the data obtained from the scanner (TLS) (KJ Cook, 2017), LIDAR data, (MA Fonstad et al. 2013), total stations, can be used. GPS equipment and RTK GPS control points (D. Turner et al., 2015).

The UAV equipment's area of applicability is spread through various civil applications, including reconstruction of high-resolution surfaces (Anders, N et al., 2013), documentation of cultural heritage and archaeological sites (Remondino, F. 2011), detection of agriculture and forest change. (Zhang,C.; Kovacs, JM., 2013), disaster management support (Maza, I., and colab., 2011) topography and mapping (Siebert, S.; Teizer, J., 2014) land management (Barnes, G.; Volkmann, W., 2015) and wildlife observation (Koh, LP, Wich, SA., 2012). In this context, Pajares offers a detailed review of the broad spectrum of UAV-based remote sensing applications (Pajares, G., 2015).

2. MATERIAL AND METHOD

Terrestrial Laser Scanning (TLS) represents a technique for 3D data acquisition and detection, from a distance it is also an active light detection technique (LIDAR - Light Detection and Ranging). This scanning technology is well known for the precision of measurements and the accuracy it can achieve. TLS is a laser scanner used with confidence to produce the cultural heritage documentation

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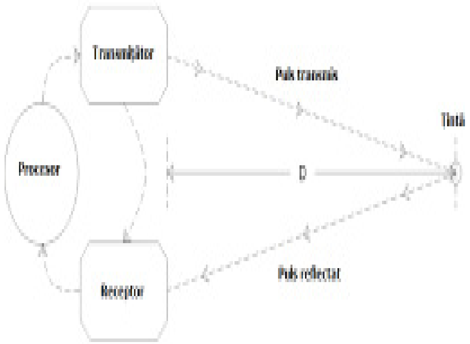


Figure 1. TLS measurement concept

The basic measurement for any laser scanning system is based on the principle of measuring the difference between transmitting and receiving the laser signal and the distance between the sensor and the object (Figure 1).

The formula used to measure the distance that the pulse sends (pulse transmitted) to the target and the time required to receive the signal (reflected pulse) back is shown in Figure 2.

$$D = \frac{(c.t)}{2} \quad (1)$$

Where:
D = distance;
c = speed of light in the air;
t = the time between sending and receiving the signal.

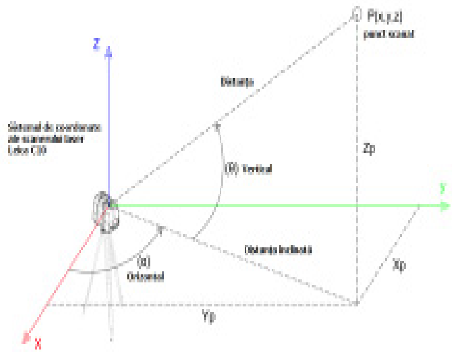


Figure 2. The principle of a laser scanner

Figure 3. Terrestrial Laser Scanner

Figure 4. 3D scanning of the lens - NH Coşteiu

The site for scanning and obtaining point clouds is located in Costeiu locality, in Costeiu Hidrotehnic Node. This objective has as a purpose of making connections between the Timis River and the Bega Canal in 1758. The hydrotechnical node was built in 1758, with the aim of drying the Timis River in dry weather in the Bega Canal, in order that the latter one to have a constant flow. This regulates the flow of the Bega channel, which provides the drinking water (for part of the city of Timisoara) and the flow required for navigation. At the same time, the hydrotechnical node from Costeiu performs the function of defense against floods.

For the measurements we used a high precision 3D laser scanner from Leica, the Leica C10 ScanStation model, which records the geometry of surfaces and structures, thus rendering the digital image of the scanned lens (Figure 4).

To complete the digital model for the top of the heritage objectives we used the UAV technique that was correlated with the TLS (Terrestrial Laser Scanner) technique.

Using the UAV proved to be extremely useful, because through 3D scans from the ground it was not possible to do a full scan to the top of the roof, but this could be done through multiple flights with a UAV equipment (Phantom 4 Pro) and to finally get clouds of dense points. Roof consolidation and overlap over point clouds (Point Cloud) resulting from TLS scanning was achieved by geo-referencing cloud points using common points. The end was spectacular because we could have a clear vision on the heritage objectives from both sides and seen from above.

In ground data acquisition applications for hydrotechnical nodes and beyond, the acquisition of construction information and other hydrotechnical elements by aerial photogrammetry is not always possible due to the coverage of vegetation detail elements. This problem can be overcome by using a ground laser scanner. In this study, a TLS laser scanner from Leica, the C10 model, which has an acquisition range from 0.6 m to 300 m, and which also has the possibility to purchase images through an integrated camera, making 260 RAW images from each station.

3. RESULTS AND DISCUSSION

The present work consists in the realization and processing of the first set of field measurements with the ScanStation Laica C10 scanner, for the Coşteiu Hydrotechnical Node (Figure 5).

Figure 5. 3D Scanning of the Costeiu Hydrotechnical Node

Measurements realization, using the Leica ScanStation C10 scanner can be presented in four stages, namely: measurement planning, actual scanning, downloading of the device and data processing. In the data processing stage, the quality assurance of data and their control are taken in consideration.

To be able to plan the measurements it is important to know what the purpose and the requirements of the project are. The aim is to create a digital database and create a 3D heritage documentation.

When planning the number of stations, the visual scanning field of the instrument (360 degrees horizontal x 270 degrees vertical) will be taken into account. Very important is the distance of measurement and the density of the points we want to collect. Depending on these parameters, the dwell time for each newly created station will be determined, as well as the scanning speed, which can be oscillating as well as rotating, the method being automatically selected by the scanner according to the characteristics of the area to be scanned, so as to ensure maximum speed.

The scan step. Most of the time the object to be scanned is too large to be scanned from a single position. Therefore, it is often necessary to perform scans from multiple positions linked to each other using targets located at different heights. Thus the patrimony objective comprises a number of 9 stations. The measurements were made in the field in 2018 (Figure 6).

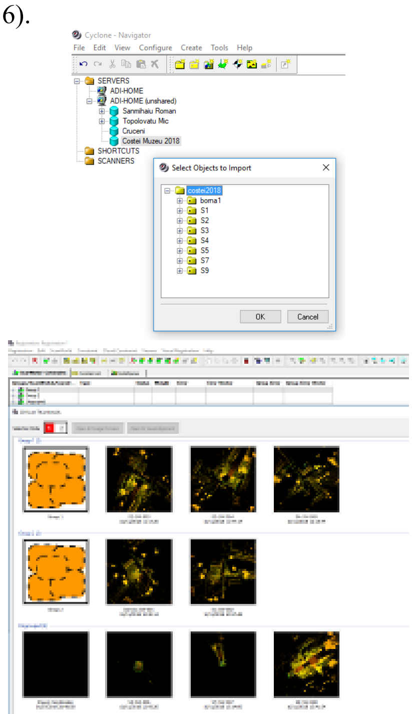


Figure 6. SmartAlign realized with the program Cyclone 9.1

The dwell time for each scan was between 25-75 minutes, in the case of the scans performed in the present work, at a GRID of 2 cm of scan. During this time, the Leica C10 scanner (TLS) used for scanning analyzes the maximum distance set for scanning, and depending on the size of the GRID, the dwell time will be determined.

The 3D laser scanner records three-dimensional (xyz) points by measuring the horizontal and vertical angle and of course the spatial distance to each point. The measurement of distances is done electro-optically by the impulse or phase difference procedure, depending on the type of instrument. By using simple trigonometric functions, the point coordinates are obtained in a Cartesian coordinate system, proper to the scanner. The horizontal and vertical angles are changed automatically, with predetermined intervals, a full 360-degree scan can be performed or by establishing an angular range, where scanning and capturing images will only be done at this angle.

Each scan was performed on the topographic principle of orientation of the device using the method of known coordinates, coordinates marked in the field by FENO type terminals, whose coordinates were determined by satellite measurements using the STATIC method of determining the position and recording the RINNEX data at an interval of 5 seconds.

The terrestrial laser scanning system allows high resolution RAW photography that can be georeferenced and used for spatial data analysis and texture processing. For scans I used 6-inch targets as well as Black & White targets.

Downloading the device and transferring data can be done using the Lemo jack with a GEV228 cable for connecting to the laptop or copying data directly to USB devices.

Data processing and obtaining point clouds.

The processing of the measurements, as mentioned above was done with the Cyclone program 9.3 version 9.3.1. The position of each scan station is defined by the coordinates entered in the scanner. In order to achieve the alignment of the scan positions it is necessary to know the position and orientation according to a coordinate system. After the scans are entered in the Cyclone program, the scans are aligned.

The alignment of the scans performed from different stations in a single common station can be done either with the Smart Align option (direct station alignment technique) or through a 'Manual registration' (indirect station alignment technique) called georeferencing (Figure 7, 8).

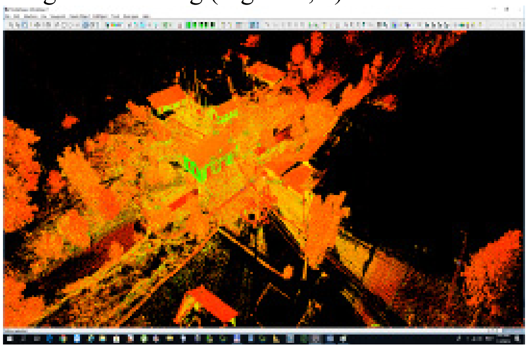


Figure 7. Point cloud obtained after alignment (colors used by the scanner)

The registration of the resulting point clouds from different stations consists of introducing the scans called 'ScanWorld' in a single 'Registration' registration and adding automatic constraints of the 'Control Spaces' cloud points.

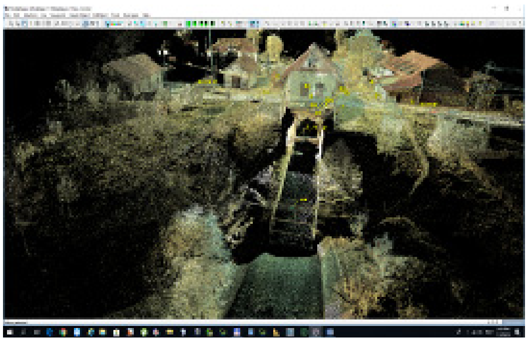


Figure 8. Point cloud obtained after alignment (colors taken from images taken by the scanner)

The alignment of the scans performed, from different stations in a single common station, can be done either with the 'Smart Align' option (direct alignment technique) or through a 'Manual Registering' (indirect station alignment technique) that carries the name of georeferencing, and in the end we can also perform a preview of the scans (Figure 9), the constraints and the errors registered (Figure 10 and 11).

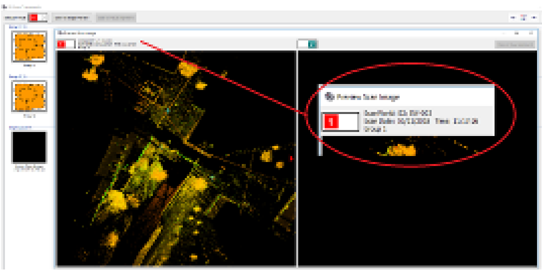


Figure 9. Preview scans

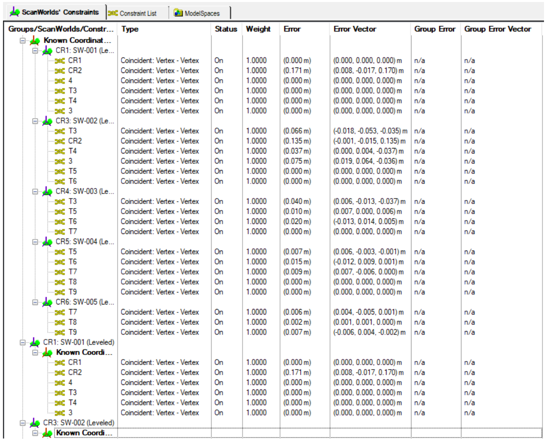


Figure 10. Constraining scans

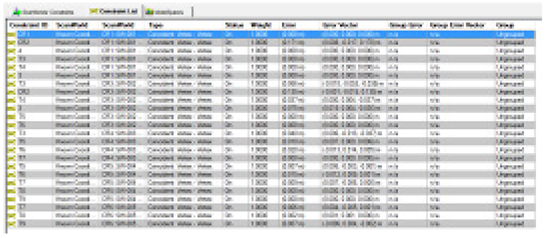
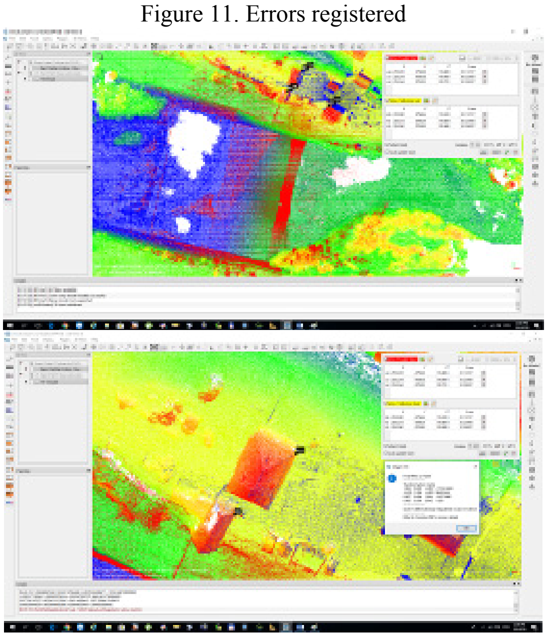


Figure 11. Errors registered



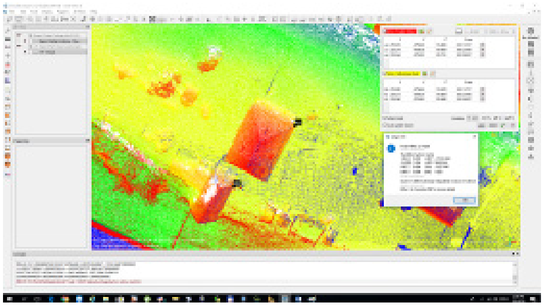


Figure12. Align the UAV point cloud with the TLS cloud

It is important that after the alignment of the points the noise points (the unwanted points) are eliminated. In addition to this, automatic functions can be used, which can segment point clouds according to the desired intensity.

With the help of the 'CloudCampare' program you can reduce the number of cloud points (pint cloud) for better maneuverability and visualization.

With this help of this program we also made the alignment of the point clouds obtained from the UAV Phantom 4 Pro flights to complete the upper parts (for example the roof) by identifying as many common points of cloud points resulting from the ground scan with the ScanStation Leica C10 scanner (Figure 12).

At the end of the paper the data were exported in different formats requested by the architect: * .E57; * .Ptx; * .X, y, z. For the presentation and visualization of the historical monuments, a directory link has been created, which can be accessed directly, and with which a virtual tour of the heritage TruViewSetup32-309.exe.

The TruView site map is a panoramic (360 degree) image of data from cloud points, the point of view being located in the same location as the scanner that captured the point clouds. The TruView point of view is made exactly from the location where the scanner was placed and where each lens was scanned. With the help of this program you can make, around the scene, magnifications and decreases, extracting the dimensions from one point to another, extracting coordinates but will not be able to fly around the scene as in some 3D systems.

Often, a single project uses multiple scanner locations. Thus, after completing the TruView link, one could switch from one location of the scanner to another to have different points of view within the project. Each point of view has a separate ScanWorld. The site map contains image icons located in the center of each available TruView scene, where with a single click on a triangle icon, we will have another viewpoint from another station. The TruView program launches directly from Internet Explorer.

The data processing, obtaining the TruView link, as well as the data processing report and the errors registered when performing the scans for the Costeiu Hydro technical Node, are shown in Figure 13.

Figure 13. TruView link for NH Costeiu

In the Figures 14, 15 and 16 are presented the 3D point clouds obtained from the ScanStation Leica C10 terrestrial laser scan in the presented work.

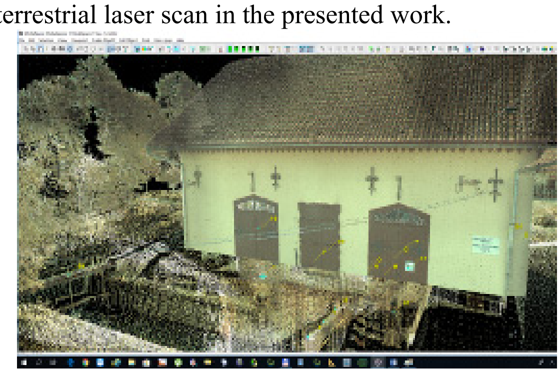


Figure 14. The building that houses the museum

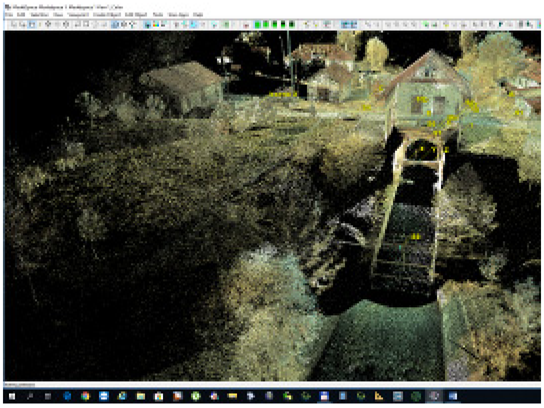


Figure 15. The downstream channel

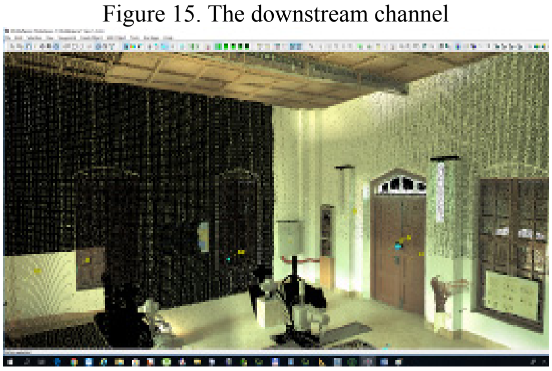


Figure 16. Inside the museum located at the Coșteiu Hidrotehnic Node

CONCLUSIONS

The popularity of the terrestrial laser scanner (TLS) has been introduced in the field of surveys and has grown amazingly especially for achieving the 3D model of heritage objectives.

When we talk about Terrestrial Laser Scanner (TLS) we are talking about the high precision of a measurement, with errors of the order of millimeters, measurements that can accurately reproduce the scanned models, and can be used for their reproduction at different scales.

The importance of 3D models made with terrestrial scanners is highlighted today by the practical applications made in many areas such as: historical monuments, preservation and monitoring of churches or other old buildings, cultural heritage, architecture, archaeological studies, bridge structures, risk assessment of instability, slopes, transport corridors, wells, mines and other underground surfaces.

The 3D modeling also known as MESH is the process of representing a surface through a specialized program.

Historical buildings play an important role in the scenario of cultural heritage, and their main value is given by age, artistic and structural characteristics, as well as by the environment.

The rehabilitation and preservation of the historical architecture include consolidation, adjustment of geometries and other technical procedures. 3D laser scanning technology is one of the important technical methods for acquiring spatial data. Typical total stations can measure up to eight distances per second, in contrast, the 3D laser scanner is capable of measuring up to 50,000 points/second.

Such equipment has also been used in research, the Leica C10 model, which is a device that includes a high-precision scanner with a long-range, tilt sensor, auto-adjustable camcorder and optical laser, all of which are introduced in a single portable device. This tool also shows major productivity gains, including a Smart X-Mirror design that has enabled full 360/270 degrees scanning or small area scans with Smart X-Mirror oscillator module.

This instrument has a range of 300 meters, capable of scanning both inside and outside, and this makes HDS (High-Definition Surveying) profitable in the field of civil construction, topography, monitoring, scenes such as accidents and forensics etc.

The positive and negative aspects recorded in the research will be presented below.

Positive aspects of using the Leica C10 scanner:

- High precision 1-10mm;
- Relatively short processing for obtaining point clouds;
- Auto-align the scans;
- The possibility of creating a 'Registering Manual' for scans that cannot be automatically aligned and presents scanning errors;
- Alternative use of the two batteries, with the possibility of changing the battery during scanning by pressing the pause button;
- Making 260 images from each station;
- The possibility of collecting up to 50,000 points/s with high accuracy;
- Scanning distance up to 300 meters;
- Full 360 degree scan horizontally and 270 degrees vertically;
- The possibility of choosing the GRID scan from 1mm to 10cm and more;
- Possibility of using Black & White targets that can be listed on a printer.

Negative aspects:

- Use of topography knowledge regarding the use of total stations (orientation and back-intersection);
- Relatively long time to perform a scan, while of course it is influenced by GRID and the maximum distance to which the scan is performed. For example, at a distance of 100 meters with a 2.5 cm GRID (used for scanning heritage hydro technical objectives) it lasts 45-50 minutes/station;
- Time allocated for moving to the station and carrying out a new retro-intersection;
- Permanently targeting and determining targets;
- Making multiple stations from different angles, especially when the scanning lens has many corners;
- Relatively expensive 6 inch targets, about 350 Euro/target.

In conclusion, 3D laser scanning technology can quickly acquire points thus forming a cloud of 3D points with a high level of accuracy.

With the help of the Cyclon Model program used for data processing, trees, pillars, roads and other topographic elements of the land could be easily extracted for the realization of a numerical model of the land, the processing of the facades of the constructions, the realization of the situation plans, cross-sectional and longitudinal profiles, and at the end we were able to obtain information regarding the X, Y, Z values of the points, the distance between two points or objects, as well as the realization of a virtual flight over the scanned objective or a virtual tour where we can also have information about the point clouds, distances and also at the end the creation of a 'link' that can be transmitted further to the interested units and the import of this data on the web page so that it can be accessed by anyone.

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