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3D LASER SCANING FOR SURVEYING APLICATION

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Abstract

3D Laser Scanning, also known as terrestrial LIDAR, has been commercially available for several years, providing a detailed, reliable, and accurate solution to many surveying and measurement problems, and has become well adopted for plant and facilities applications where accurate three-dimensional detail of complex facilities is critical for efficient design and construction projects. Terrestrial laser scanners deliver a dense point-wise sampling of an object's surface. For many applications a surface-like reconstruction is required. The most typical example is the visualization of the scanned data. In many respects, laser scanning follows the same general surveying process as other instruments: data is collected in the field, adjusted to the appropriate coordinate system, and relevant features can be extracted to produce deliverables ranging from topographic maps, coordinate values, 2D or 3D CAD drawings etc. This paper describes typical scanning project from field-to-finish, including common surveying applications.

Key words*: 3D Laser Scanning, surveying and measurement, surveying applications, Romania, topographic.*

INTRODUCTION

Years ago, the measurement of any object was exclusively done with theodolites or total stations. With the increasing usage of 3D CAD design tools the need for better, more accurate and faster 3D measurement grew in parallel. 3D Laser Scanning describes a method where a surface is sampled or scanned using laser technology. The word LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. The first working laser was demonstrated in May 1960 by Theodore Maiman at Hughes Research Laboratories. The data collected through laser scanning can be used to construct digital, two-dimensional drawings or three-dimensional models useful for a wide variety of applications. In the early stages, laser scanning was short range and mainly used in the automotive and industrial design process to facilitate the Computer Aided Design (CAD) process. Mid-range scanners were developed for the petrochemical industry. Due to the complexity of plants, which were only documented as 2D drawings, laser scanning led to the full 3D management of sites. When laser scanners were introduced on the market, their performances were rather poor, having in general a measurement uncertainty in the range of centimetres. From a user's point of view, a 3D scanner is any device that collects 3D coordinates of a given region of an object surface automatically and in a systematic pattern at a high rate (hundreds or thousands of points per second) achieving the results (i.e. 3D coordinates) in (near) real time. The technology advances have allowed the surveyor to take advantage of new tools to complete the same surveying tasks that have been performed for hundreds of years; for example, boundary surveying, topographic mapping, as-builds, volume calculations, etc. With few exceptions, these new technologies did not change the methodology, processes, or best practices of the surveyor.

MATERIALS AND METHODS

At present there is no standard procedure for survey planning for terrestrial laser scanning.

However the key to success in using 3D laser scanning remains the setup and implementation of the right methodology and workflow "fit for the job", combined with the selection of the most appropriate hardware and software. According to the laser scanning users' community, the survey planning should at least contain the following topics:

-Determining the goals and objectives;

-Analysing the area to be surveyed;

-Determining the measuring techniques and equipment;

-Data management.

Surveying with a 3D laser scanner generates a new set of information – the point cloud. A point cloud can be compared with photogrammetry in that it is derived from a remote sensing instrument, that is, the measurements are taken without physically contacting the target area. Lastly, a comparison can also be made to remote sensing satellites, as additional "non-positional" data is collected from the raw measurements, such as the signal intensity of each point in the cloud, which will vary based on the reflectivity of the scanned object. Each point in the point cloud is measured with respect to the scanner position, and similar to photogrammetry, the position of the scanner (the camera) does not need to be known during the measurements. Aligning the point cloud to local control with laser scanning is similar to photogrammetric control, as overlapping targets can be used to join multiple scans (photos) together and to "fit" it to the desired coordinate system. The survey preparation phase includes the decision making on the registration technique to be used. These techniques can be subdivided into three categories: registration using 3D re-sectioning of scanned targets, registration by setting the laser scanner over known control points, and registering using cloud to cloud constraints.

Figure 1 - Target types

To collect data used in our example we used a Leica ScanStation2 scanner with 4 artificial targets (Figure 1) that are made from highly reflective material and their reflectance value is much higher than its surroundings. Before starting the scanning, the scanning device itself was connected to a laptop that can receive and store all the points coming from the scanner and control the properties of the scanner through Leica HDS Cyclone software. This software provides the tools to automatically detect artificial targets in the scan.

The Leica Scan Station 2 is a pulsed type, laser Class 3R , laser scanning system that has a modeled surface precision(noise)of 2 mm, an scan resolution of 6 mm (Gaussian - based) for position and 4 mm(FWHH - based) for distance at a range of 0m-50 m, the maximum range being 300 m at 90% (134 m at 18%) and a maximum instantaneous scan rate up to 50.000 points/sec. The maximum field-of-view (per scan)of the scanner is 360° horizontal and 270° vertical and has a optical sighting using the Quick Scan™ button.

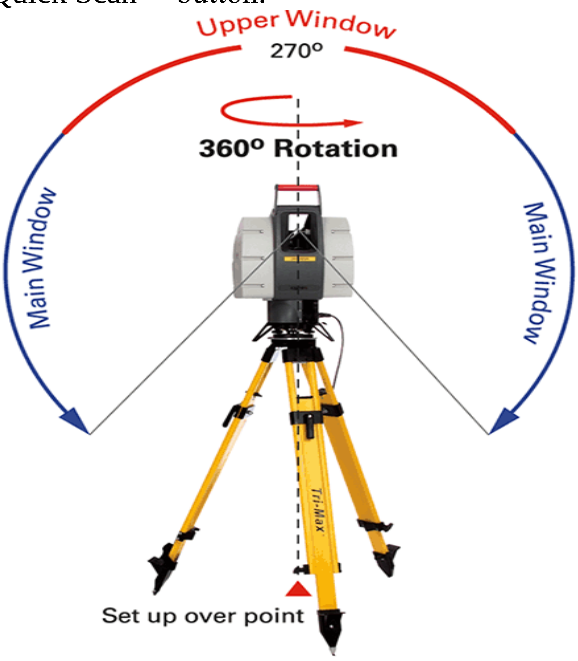

Figure 2 - Leica Scan Station2

RESULTS AND DISCUSSIONS

Using a laser scanner to record a building is not just pressing a button and waiting for the deliverables to come out. It requires a profound knowledge of the equipment and the scanning process. Some of the steps of the scanning process are quite automated while others are still labor intensive. Most surveying tasks, including topographic mapping and as-builds, are typically done at close range to obtain the appropriate level of detail. In order to geo-reference the point cloud(s) to an existing local coordinate system, at least 3 known points in Northing, Easting, and Elevation(NEE) are required on the site. As with most surveying practice, the minimum will provide the answer but will not allow for any checks; typical field procedure suggests setting up and locating more targets than the minimum to isolate and account for uncertainty. The surveyed targets must also be geometrically positioned on the site such that the registration produces an accurate result. Similar to photogrammetry, it is important to place targets that form a strong geometric configuration across the project site. Once the targets are placed in the scene, terrestrial measurements are then made with GPS and/or an optical total station to measure and record the local coordinates of specialized scan targets. These targets are then scanned at a high density. A “fine scan” is done on each of the targets to ensure accurate modeling of the vertices, or geometric centers.

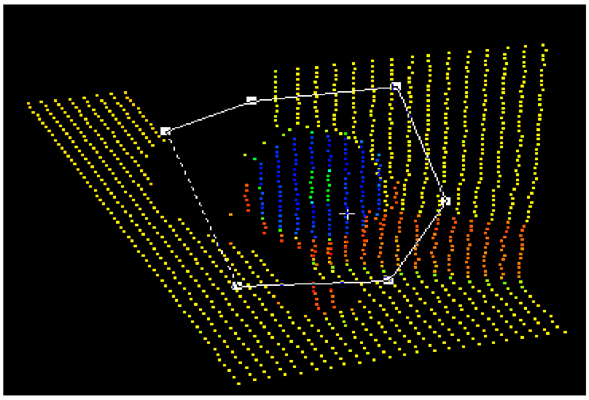

Figure 3-Target fine scanning

Laser scanners are line-of-sight instruments, so to ensure complete coverage of a structure multiple scan positions are required.

In our example we used the target-to-target registration to register the two scans, that we made, and obtain a point cloud 3D model of the laboratory. A number of 4 artificial targets were placed in the scene before scanning, matching them all between “ScanWorlds” allowed us to register these scans. Each scan position is defined in a scanner coordinate system and to be able to align different scan positions, it is necessary to know the exact position and orientation of these scanner coordinate systems according to a local or global site coordinate system.

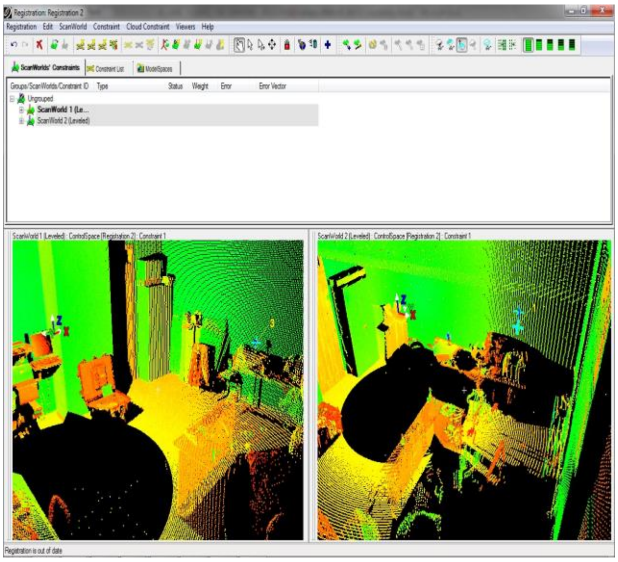

Figure 4- Target registration of the two scans in Leica Cyclone

After the registration is complete, all points from the scans can be viewed, stored, and exported in the local coordinate system. Once a point cloud is registered to the local coordinate system, measurements can be made between any points or surfaces of a structure (checking against setbacks, property lines for encroachment or clearances between structures) directly in the point cloud. At first glance, viewing the volume of points in a point cloud can be overwhelming to the surveyor, as it is difficult to imagine capturing over a million points in a topographic survey.

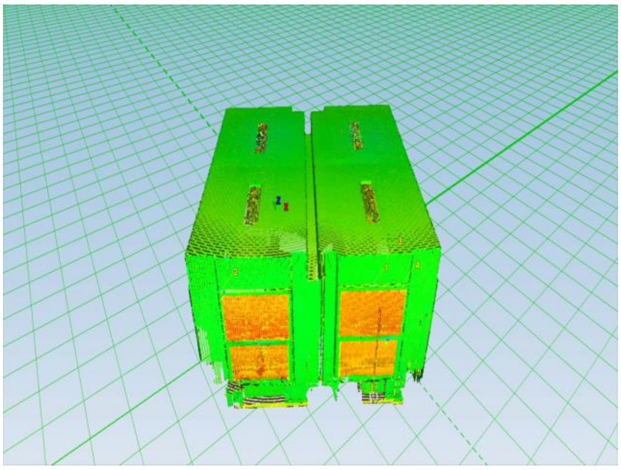

Figure 5- Perspective view of the registered and cleaned point cloud of the laboratory

With a conventional total station or with GPS, the experienced surveyor typically captures the minimal amount of points to represent the target surface, collecting and annotating data about features in the field. As with all measurement techniques, this process is prone to costly errors and/or omissions in the data, and can sometimes be impossible to collect on the site due to traffic, toxic or prohibited areas, and inaccessible regions. With 3D laser scanning, many of these errors are eliminated based on the fact that scanning blankets the site with 3D points at a user-specified resolution..

Point cloud processing means the process of transforming the raw registered point cloud into a final deliverable. These deliverables come in a wide variety of formats: cleaned point cloud data, standard 2D drawings (e.g. plans, elevations, cross-sections), fully 3D textured models for walkthrough animations. Some examples of how a point cloud can be quickly utilized to produce a variety of deliverables:

-Work with the raw point cloud in Autodesk AutoCAD, Micro Station or other CAD software, in order to create a 2D or 3D survey drawing.

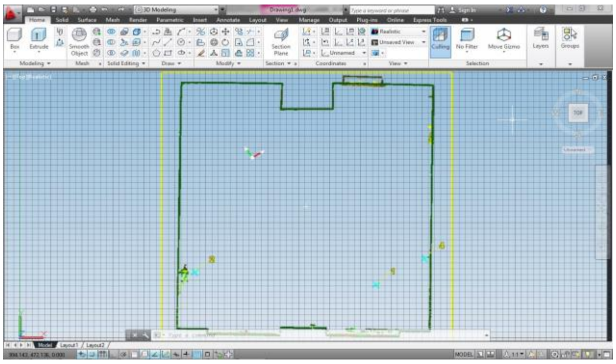

Figure 6- 2D Floor plan of the lab exported in AutoCAD 2013

- Extract feature codes directly from point cloud, export to feature code processing software;
- Calculate volumes or surface areas directly from the point cloud
- Create and export a digital terrain model, generate contours of a selected area automatically
- Measure between any points in the point cloud, including elevation differences, slope or horizontal distance.

Often, scanner companies show impressive videos of point clouds turning into fully textured models in less than one second. In reality this process is still very time consuming and is mainly a manual process. Deliverables can be extracted straight from the point cloud without further processing, or by first creating a 3D surface model from the point cloud and extracting the deliverables from this surface model. The second method is more efficient because there are automated tools to generate multiple cross-sections from a meshed model and the surface model adds more value and understanding than just a raw registered point cloud.

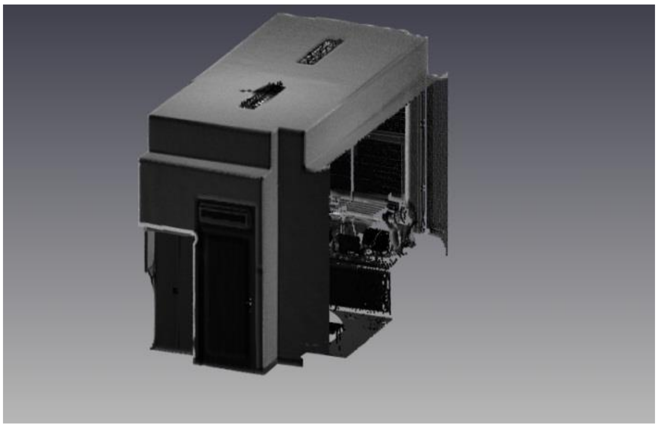

Figure 7- Perspective view of a section in the 3D model of the laboratory

One of the most familiar aspects of collecting topographic data for the surveyor is “coding” point and line features in the field, such that line work and symbols can be automatically generated in the office. Feature coding with GPS or terrestrial total station instruments is performed at the job site, where each point is physically occupied by the surveyor for seconds and sometimes minutes.
Reflectorless instruments allow these features to be coded at the instrument and a code is typically entered for the measurement. Feature code “libraries” are typically used to store a list of specific point and line codes, these libraries may differ based on the deliverable or the equipment/software being used by the surveyor. Mapping irregular surfaces such as drainage ditches, landfills, stockpiles, or common site surveys typically have involved the collection of tens or even hundreds of ground points to generate and accurate digital terrain model (DTM). A DTM is typically created from a digital elevation model (DEM) or a triangulated irregular network (TIN). With 3D laser scanning, the process of generating contours is greatly improved in both the field and in the office, due to the rapid collection of a massive amount of ground data and specialized software tools to generate a TIN. Once the TIN is generated, it is possible to perform several surface-related functions like, surface area and volumetric calculations, contour creation, cross sections and profiles.

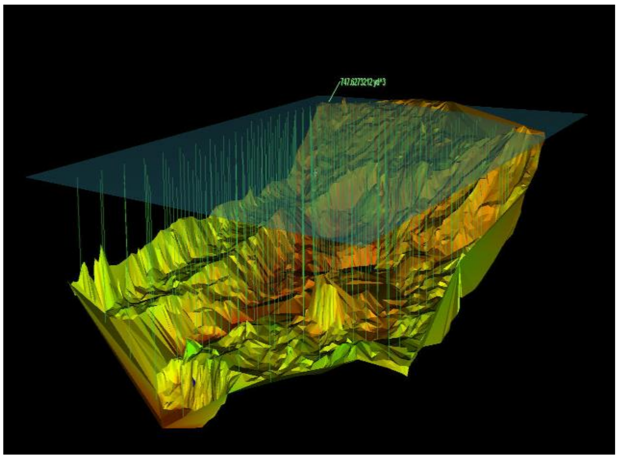

Figure 8-Calculating volume of a meshed pit

Figure 8 shows the volume of a hazardous pit as derived from a single scan of the site conversed in to a mesh with Geomagic Studio® software. Because the modeling or meshing step is one of the most computational and time expensive steps in the whole processing process, we only exported the required data for processing.
In this calculation, we defined a geometric plane, that represents the top of the pit or the existing grade at the base of a landfill, to which the volume measurements are made. It is also possible to make measurements from a specified elevation. Once this reference plane was established, a sampling rate was selected that indicates the density of the “virtual rod readings” made relative to the reference plane. Based on this information, the volume is displayed in the desired units. Data such as TIN models, cross sections, and feature codes can be created and exported using the local coordinate reference. Surveyors commonly produce accurate as-built surveys of structures such as buildings, bridges or roads, usually for the purposes of checking engineering or building code compliance. In addition to these purposes, as-built surveys are also created for preservation/conservation, construction archiving, fabrication inspection, interference design checking, etc .
One of the final requested deliverables is a 3D model of the masonry vaults with very high accuracy, so that it can be used to perform a finite element analysis for structural deformation measurements.

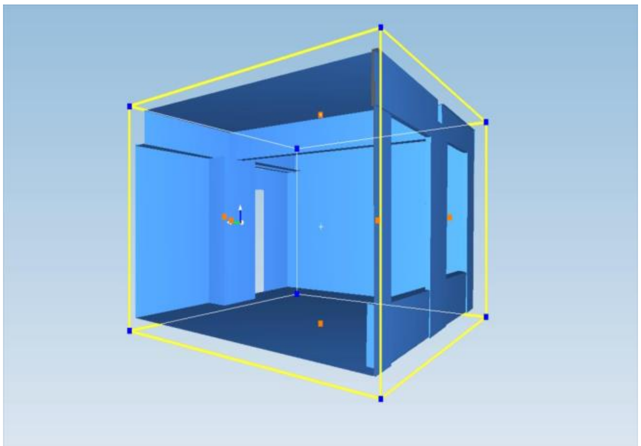

Figure 9- Perspective view of a section in the meshed 3D model

Generally, complex structures like these are meshed, which means that all the points are transformed into surfaces by connecting them through small triangles.

CONCLUSIONS

Today, the typical surveyor has multiple microchip-based instruments at their disposal, including GPS, laser levels, and robotic total stations. More and more, surveyors are complementing their suite of measuring equipment with 3D laser scanning instruments, with the goal of enriching their tool chest with the unique measuring capabilities that the scanner represents.

The main advantage of laser scanning is the fact that it can record huge numbers of points with high accuracy in a relatively short period of time. The reason for recording an object or building is that it can provide an insight on the requirements concerning the deliverables and their accuracy. The use of laser scanning generates accurate, reliable and comprehensive digital information available for sharing in a reduced survey time. The risks of engineering errors are extremely low, thanks to the availability of a high number of precise 3D points, and field fitting activities can nearly be eliminated thanks to the obtained precision during the preceding stages.

As a consequence the usual financial uncertainties for these kinds of projects are much more under control:

- Only one well defined measurement campaign, holding more information than immediately needed. The 3D data file of the scan of the site allows the user to get dimensions after the fact and without having to go back to get more information;
- Improved overall project planning thanks to the improved reviews and the information sharing;
- Quasi elimination of reworks and field fitting leading to controlled and limited downtime.

Moreover, the use of laser scanning has a major impact on the safety issues as the measurements are taken from a distance, the measurement teams can chose the most suitable scanning locations and thanks to the rapidity of the laser scanning, the exposure to the risks is also much shorter.

As the design-build process becomes more advanced, requirements for better accuracy and more detail in the construction process will be necessary. It is clear that the 3D laser scanning is the future of surveying because it provides a detailed, reliable, and accurate solution to many surveying and measurement problems.

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