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3D LASER SCANNING FOR MAPPING, BUILDINGS AND HERITAGE

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Abstract

The paper aims to present the generalities and areas of use of laser scanning and its use. Laser scanning technology is among the latest methods of collecting geodata. Is applicable especially in areas which use high precision 3D data. In brief, laser scanning principle is the following: sending a laser beam to measure the distance from the source to the surface or object searched. At the same time, is recorded the direction. By evaluating parameters are obtained information about a specific object on the surface. The laser can be set statically on the ground (terrestrial laser scanning) or a plane or helicopter (aerial laser scanning). For special applications, laser scanners may be located in a vehicle. The main product of laser scanning is a set of 3D coordinates of the points reflected called "point cloud", and with these automatic, semi-automatic and manual procedures, these points are classified by further processing.

***Key words**: 3D, laser scanning, buildings, mapping, point cloud, coordinates.*

INTRODUCTION

Laser Scanning describes a method where a surface is sampled or scanned using laser technology. It analyzes a real-world or object environment to collect data on its shape and possibly its appearance. The collected data can then be used to construct digital, two-dimensional drawings or three-dimensional models useful for a wide variety of applications.

The 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. It is like taking a photograph with depth information. Laser scanners are line-of-sight instruments, so to ensure complete coverage of a structure multiple scan positions are required.

The laser scanner technology can be divided into 2 categories: static and dynamic. When the scanner is kept in a fixed position during the data acquisition, it is called static laser scanning. The advantages of using this method are the high precision and its relatively high point density. All static laser scanning can be seen as terrestrial laser scanning, however not all terrestrial laser scanning can be categorized as being static laser scanning. In cases of dynamic laser scanning, the scanner is mounted on a mobile platform. These systems require additional positioning systems such as INS and GPS which makes the system 13 more complex and expensive. Examples of dynamic laser scanning are scanning from an airplane (airborne laser scanning), scanning from a moving car or from an unmanned aerial vehicle (UAV). (3DRiskMapping, 2008)

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 process. This helped in the mass production of consumer products.

Because the obvious advantages of laser scanning like: non-contact measurement, high accuracy, long range, fast data acquisition, etc., other disciplines like cultural heritage, architecture, urban development, forensics, and the entertainment industry are starting to steadily adopt this technology.

MATERIALS AND METHODS

Nowadays, there is no classic procedure for terrestrial laser scanning. Most CAD and modeling programs construct geometry from only a few sample vertices and estimate the rest with design assumptions. Design or modeling packages aid the user in creating entirely novel

models from a conceptual model or idea. Cyclone software provides a high-performance environment for manipulating point cloud data captured by High Definition Surveying (HDS™) systems. Cyclone enables the user to accurately visualize, navigate, measure, and model 3D objects and scenes.
The first time you run Cyclone (Figure 1), you need to create a new database, or connect to an existing database, on the desired server. Databases can reside on your local server or any connected server across a network and stores all Cyclone data including Projects, ScanWorlds, ModelSpaces.

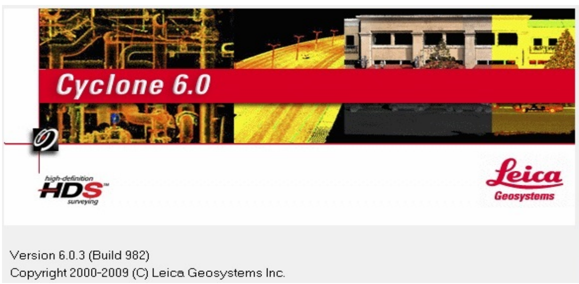

Figure 1. Leica Cyclone software

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.
To collect data in the field was used a Leica ScanStation2 scanner with 4 artificial targets which are the ideal accessories for registration purposes and quality assurance. They allow for accurate geo-referencing of scans to known control points, accurate registration of multiple scans to each other, and valuable quality assurance for individual scans.
Once the site documentation is gathered and laser scanning has been chosen to be the most effective recording technique, the scan and target positions need to be planned.
The optimal locations for the scanning station should be chosen to guarantee a maximum coverage and accuracy while minimizing the number of setups.
Next to the optimal scanner locations, the target types and their positions and/or geometric configuration are also important. Targets are mainly used to register scans taken from different scan positions. Currently there is wide variety of target types available: retro-reflective targets, spherical targets, paper targets or prism targets.
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 Cyclone software. This software provides the tools to automatically detect artificial targets in the scan. (3DRiskMapping, 2008).
The Leica ScanStation 2 high speed laser scanner(Figure 2) is fast-becoming one of the most versatile and productive tools in a surveyor's toolbox. This is the only scanner in its class to provide full 360° x 270° field of view from a single scan for added site versatility and productivity and is able to achieve single point positional accuracies to 6mm at 50m, with 300m maximum range.
It fires at 50,000 points per second, the fastest in its class and its sensors automatically compensate the captured scan data for any drift of the scanner from vertical during a scan.

Figure 2. Leica ScanStation 2

RESULTS AND DISCUSSIONS

When a laser scanner is used, the user must have a profound knowledge of the equipment and the scanning process. It is of great importance to double check the scan's completeness when the scanning is finished. Realizing a part is missing in the scan data when at the office may lead to an expensive return visit to the site. The second visit might

require more time than checking the completeness on site during the first visit would have taken.
Before processing the clouds, scans affected by extreme environmental conditions or erroneous scans due to human mistakes are removed from the data set. The scans that are not removed now need to be prioritized according to the 'best views'. The prioritization is done using the field notes and sketches. In most cases, the object to be scanned is too large to be scanned from one position only. Therefore, multiple scanning positions are required. Each scan position is defined in a scanner coordinate system. 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/global site coordinate system.
For this study, as benchmarks I used the Chemistry USAMVB campus building, and the data set was obtained by four consecutive scans, without placing targets in the field.
A way of registering two point clouds is by using point cloud overlap. If two point clouds have enough overlap (generally 30 – 40%), a technique called Iterative Closed Point processing or ICP can be used to align both datasets. (Figure 3)

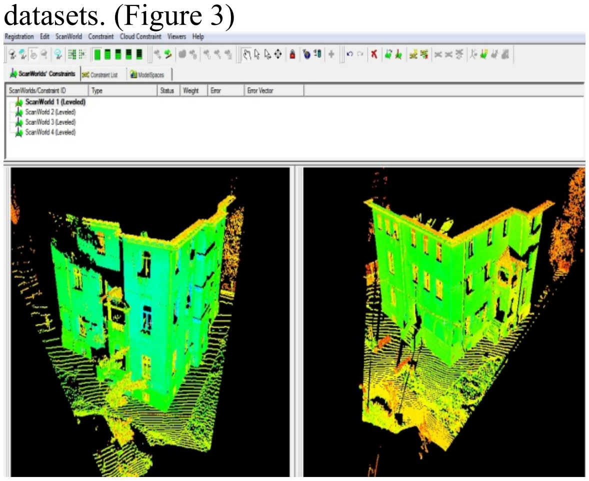

Figure 3. Point cloud registration

This technique required me to manually pick at least 3 corresponding points in the point clouds. Since these 3 points will never be exactly the same points, the ICP algorithm iteratively checks the distances between all the points of the point clouds and estimates the transformation to align both sets thus resulting in minimal error.

After registration, a point cloud processing is needed. 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. In general, the 3D point cloud processing can be divided into two categories. 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. Which method is chosen depends greatly on the required deliverables. For instance, when only a limited number of cross-sections are required, it is better to extract them directly from the point cloud. However, when more sections are needed, the second method is more efficient because there are automated tools to generate multiple cross-sections from a meshed model. (V. Balis, 2004). Furthermore, the surface model adds more value and understanding than just a raw registered point cloud.

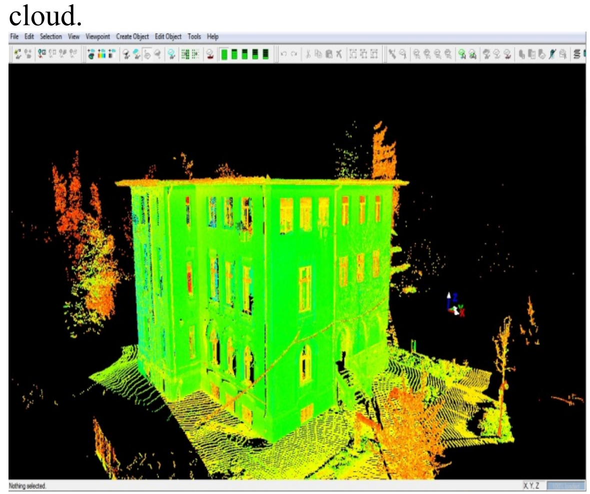

Figure 4. Point cloud processing

The result of a scan acquisition is a huge number of points in space, each having an x, y, z coordinate and usually a laser reflectance value. Some scanners even provide color information in the form of RGB values (Figure 4). The point cloud can be represented by drawing all these points on the screen, but this gives a very chaotic impression and a user will have difficulties recognizing structures from the cloud. When every point is given its reflectance value or a color value, the overall structure becomes understandable. (Figure 5)

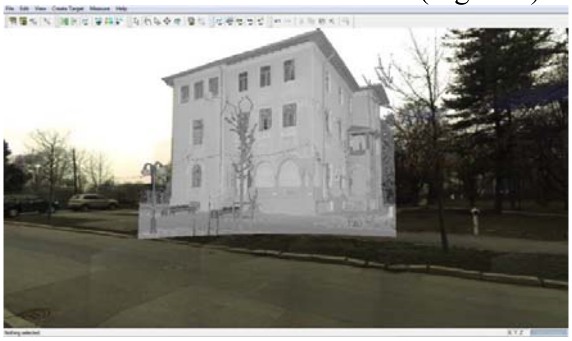

Figure 5. Perspective of the measured building (opened in TruSpace).

The primary application that I used is the conversion of point clouds to CAD object-based line and surface models. This various process employed to this end are referred to collectively as “modeling” and are applied via the ModelSpace window. The tools analyze and extract information from point cloud data and convert point clouds to CAD object-based line and surface models.

Then, the point cloud was processed by using the Fit Fenced to Cloud and Fit to Cloud submenu commands. This take only a few seconds to generate a best-fit object by indicate the type of surface to be fit for the selected point cloud, and the fitting algorithms perform a multi-dimensional minimization over the parameter space for the surface type.

For working properly it is necessary to divide or segment a point cloud into one or more subsets in order to focus further operations on a subset, remove unwanted data. Segmentation provides a process for grouping different regions of point clouds based on shared characteristics. For example the points from the north face of the building were segmented because they are unnecessary for subsequent modeling or visualization because they may be stray or unnecessary points.

To extract single points from a points cloud, you need to click on a point to observe its coordinates, because each point has unique X, Y, Z coordinates. The possibility is to import the point cloud or part of the point cloud into CAD, and it is efficient only with relatively small scan data sets. As easy as it is to extract single points from point clouds, you can't be sure that a given scan point is exactly on a corner or an edge, or represents the lowest point of a curb. Use of a single scan point in this way will depend on the accuracy required.

If even higher point accuracy is needed, then it may be necessary to create a model of the area of interest and derive the point of interest from the model. This is exactly the process that is used to locate the points used for registration. A similar approach can be applied to other objects or features.

For taking distance measurements you need to extract slope distance measurements from any two selected points.(Figure 6) This capability is very useful for quick, approximate distance measurements. Horizontal and vertical distances can also be readily extracted, provided the software has this capability. Again, the accuracy and utility of the distance measurements from the point cloud are constrained by the cloud's point-to-point spacing and the accuracy of each selected point. For more accurate distance measurements, point cloud modeling is needed.

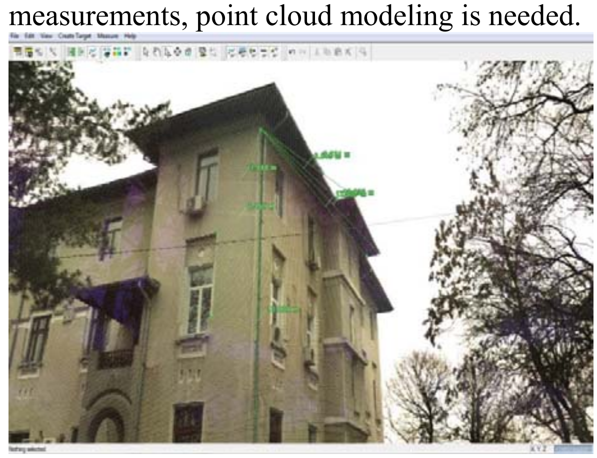

Figure 6. Measure the distance on a building in Cyclone 6.0 software

Extracting volumes from point cloud data can be a highly efficient process, which also yields more accurate volume calculations than traditional methods. Volumes can be extracted between surfaces or between a surface and an assumed plane. The process involves creating surface geometry first and then extracting volumes and surface-to-surface deviations. This latter functionality can also be useful for monitoring surface movements over time.

For extracting surfaces, many types of point cloud software have the ability to generate surface models. (Figure 7) These can be created from meshes or from CAD primitives, where appropriate. Initial work is done within the point cloud software to clean up the data and to create TIN meshes. Meshes can be decimated intelligently to reduce file size while retaining critical changes in geometry. After this step, the points themselves are often exported to civil design software for creating final DTM deliverables. Although the need to create 3D object models for civil projects is uncommon, the extraction of 3D models from point clouds is quite well developed in advanced point cloud software, as this is where most point cloud processing software began. (Figure 8) Typically, object models generated from point clouds are surface models, cylinders, planes, spheres, steel shapes, other geometric primitives, and arbitrary "catalog" shapes. Tools are also available in advanced point cloud software for applying standard spec tables, such as for piping and steel shapes. Three-dimensional object models are generated "piece-by-piece" from point clouds.

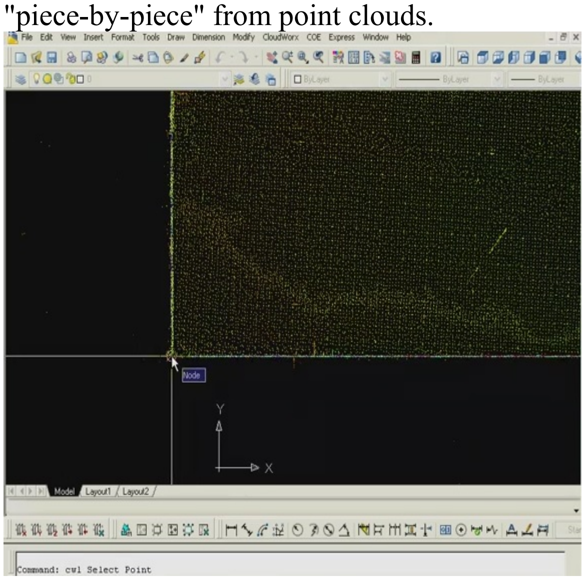

Figure 7. Editing of floor plan of the building in AutoCAD

You can click on a point that obviously lies on the surface of a building and instruct the software to fit a box using all other appropriate points near the selected point. Similarly, you may select a point on a wall or floor and instruct the software to create a plane, and so forth. Three-dimensional models can be exported to intelligent 3D design software that enables the creation of "intelligent 3D models" that represent additional attributes of the object. Three-dimensional models of irregular objects, such as statues, cars, boulders, etc. can also be created, but this involves more intensive office processing and the use of specialty software. Likewise, texture mapping can be applied to the point clouds or geometric surfaces for photo-realistic models, but this is also generally done outside of point cloud software.

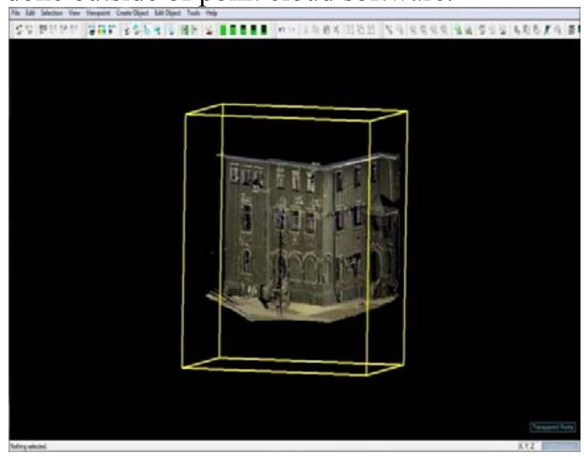

Figure 8. 3D model of the building

Another destination of laser scanning is that you can make case studies about heritage. Cultural Heritage can be defined as monuments, buildings, or landscapes of "outstanding universal value from the point of view of history, art or science." These sites are often under threat from environmental conditions, structural instability, increased tourism and development, and they are most likely under-funded, and hence, inadequately documented and maintained. Laser scanning, in combination with other digital documentation techniques and traditional survey, provides an extremely useful way to document the spatial characteristics of these sites. (Figure 9) This spatial information forms not only an accurate record of these rapidly deteriorating sites, which can be saved for posterity, but also provides a comprehensive base dataset by which site managers, archaeologists, and conservators can monitor sites and perform necessary restoration work to ensure their physical integrity (English Heritage, October 2011).

Figure 9. Use of laser scanning data for presentation of archaeology: Ketley Crag rock shelter (courtesy of Paul Bryan, English Heritage).

CONCLUSIONS

3D Laser scanning is safe because it employs eye-safe laser systems, because the principle of operation relies on the object selective illumination and laser reflection detection with no further interaction with the artwork and yet because, unlike photographic methods it's completely environmentally safe. Also, this is versatile, because can be used with many different materials, except for absolute transparent or reflective objects, in different environments, underwater inclusive, and for a large range of objects size, from archaeological sites, to very shallow and almost invisible inscriptions on stone.

3D Laser scanning can achieve accuracies of few micrometers, in objects of several meters size, allowing for the detection of very small features in the artwork surface and a very detailed documentation of the object.

However the high accuracy of the 3D Laser scanning technology has also associated inconvenient, consisting in the high data content of the image records, being time consuming and requiring high capacity and high speed computers for the image post processing operations.

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