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CREATING THE SOLID 3D MODEL OF A BUILDING USING LASER SCANNING TECHNOLOGY

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Abstract

3D Laser Scanning is providing a detailed, reliable, and accurate solution to many surveying and measurement problems, and has become well adopted for complex applications, like plants and other facilities, where accurate three-dimensional detail is critical for efficient design and construction projects. Terrestrial laser scanners deliver a dense point-wise sampling of an object's surface. The most typical example is creation of a 3D As-built model.
This paper describes a typical scanning project from field-to-finish . 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, modelled and relevant features are extracted to produce 3D CAD drawings, 2D precise plans and elevation, etc.

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

INTRODUCTION

3D terrestrial laser scanning (TLS) systems have appeared and evolved very fast in the last decade granting them a firm place in geodetic metrology. When TLS laser scanners were introduced on the market, their performances were rather poor, having in general a measurement uncertainty in the range of centimetres (Cuartero et al., 2010).
Nowadays the precision and data collection speed are far beyond what anyone could imagine 10 years ago.
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 achieving the results in (near) real time (Hook and Lepere , 2007). There are many advantages of the 3D laser scanning, including non-contact measurement, massive and precise digital data, and operation without limitation of light and weather. 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 faster and in a more precise way. So, this paper describes the workflow we, as surveyors, used to obtain the solid 3D model of a building by using the laser scanning technology.

MATERIALS AND METHODS

Surveying with a 3D laser scanner generates a new set of information – the point cloud.
A point cloud is a collection of XYZ coordinates, in a three-dimensional coordinate system, that also include additional information such as colour and reflectivity values. It 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 (Davis and Aiken, 2000) . 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. In order to geo-reference the point clouds 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 (Bornaz and Rinaudo 2004) .
We used a minimum of 4 targets on each scan, geometrically positioned on points of known coordinates for the registration to 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 were placed in the scene, terrestrial measurements were then made with two GNSS-RTK systems (CHC X91GNSS and HORIZON KRONOS 200) with a precision of 10mm on horizontal and 20 mm on vertical.

Figure 1. Measuring the coordinates of the HDS targets on top of the building

A "fine scan" was done on each of the targets to ensure accurate modeling of the vertices, or geometric centers.
In this case we used a survey control network of points of known location that defined a local reference frame in which all other measurements were referenced. The scanner used in our example is a Leica Scan Station 2 scanner and a laptop PC with Leica Geosystems HDS Cyclone Software. The laptop is used to interface and control the areas to be scanned and to visualize the data in 3D as it is collected. The Leica Scan Station2 has a modeled surface precision(noise) of 2 mm, an accuracy of 6 mm for position and 4 mm for distance at a range of 1m-50 m, the maximum range being 300 m at 90% (134 m at 18%) and a scan rate up to 50.000 points/sec.

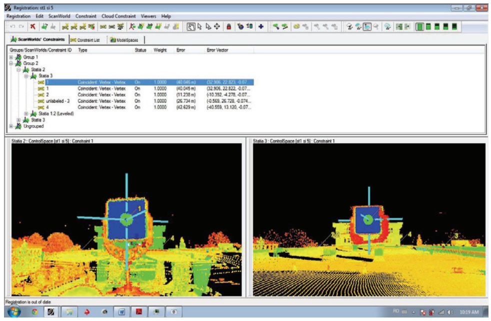

Figure 2. High density scans on special targets

Figure 3. Leica Scan Station2

RESULTS AND DISCUSSIONS

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-builds are also created for preservation/conservation, construction archiving, fabrication inspection, interference design checking, etc. As-build surveys that require a significant amount of detailed data capture of certain features of inaccessible areas can be quickly identified, located, and mapped directly from a 3D point cloud. However, there are some surfaces(any transparent material such as glass, mirrors, water, and crystal)which could not scan particularly well, because they will refract the light and give false three-dimensional information (English Heritage, 2007). 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 several million points in a topographic survey. 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 were eliminated based on the fact that scanning blankets the site with 3D points at a user-specified resolution. If the desired objects and features can be "seen" by the scanner, it can be represented accurately in the point cloud and extracted with software such as Autodesk AutoCad. Most surveying tasks, including topographic mapping and as-builds, are typically done at close range to obtain the appropriate level of detail. Regions that are not shown in one scan can be scanned with another setup, and these point clouds will be merged in the software.In our example we used 10 scans of a building witch we referenced, in Stereographic 1970 Coordinate system, and merged to obtain the 3D point cloud of the building. All the scans were made at a resolution(the average distance between XYZ coordinates in a point cloud) of 5 cm. Once a point cloud is registered to the local coordinate system, measurements can be made between points or objects, checking against setbacks, property lines (for encroachment) or clearances between structures. Engineers can make compliance measurements between any points or surfaces of a structure directly in the point cloud.

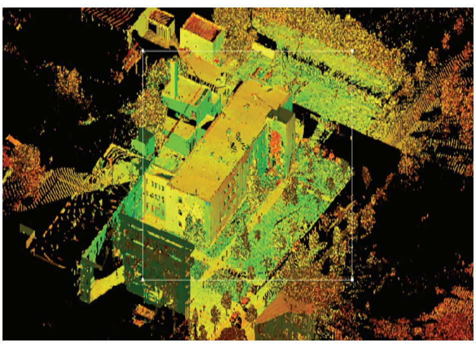

Figure 4. Top view of the raw 3D point cloud

The raw point cloud can be directly used for 3D visualization, point to point measurements just like if the user were physically present on the site and stored for subsequent use. To do this it is necessary to reduce the amount of processing point cloud data between 15–20% before the data post processing. In our case, we selected just the building, from the raw point cloud, by "cleaning" the rest of the point that were not part it. After this filtering operation our remaining point cloud had just 11 millions points left, as everyone of the 10 scans scan had a average of 2 million points.

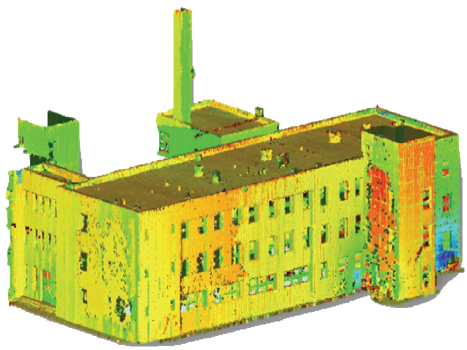

Figure 5. Perspective view of the selected building's point cloud

The resulted point cloud was then exported in *.pts format, in this way it could be used in various modeling software. Before importing the point cloud in Autodesk Revit software, we made a advanced cleaning and inspection of the point cloud in the new Autodesk ReCap software. This is a software specially created for point cloud data, in which we can modify our point cloud (by deleting unnecessary parts of it) or take direct measurements on the point cloud. We used de Autodesk Revit software to create the final 3D model using our building's point cloud. From the 3D model it is possible to realize a section with a horizontal and vertical plane in the different zones of interest and immediate measurements which are essential for huge scale and complex structure.

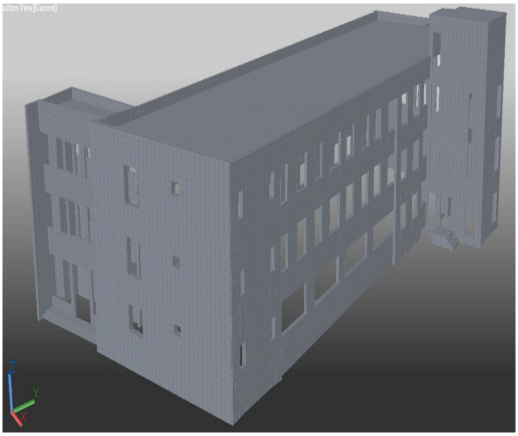

Figure 6. Solid 3D model of the building

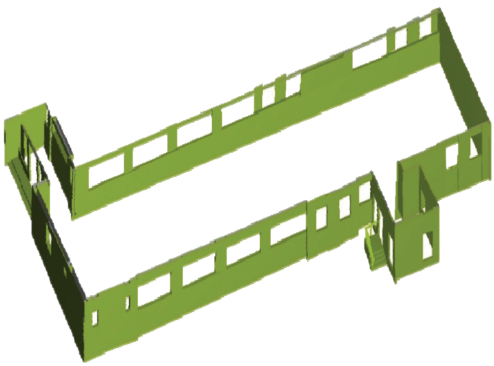

Figure 7. Perspective view of a section in the solid 3D model

CONCLUSIONS

As the design-build process becomes more advanced, requirements for better accuracy and more detail in the construction process will be necessary. The 3D laser scanning represents today's the most advanced technology available for measuring and documenting objects, structures and landscapes. The laser scanner not only performs the wide range, very fast operation and data accuracy acquisition, but also provides the point digital information including three dimensions, returned light intensity and RGB colors. Still it is very expensive, need high skilled operations and post processing can be time consuming, while editing the data to produce meaningful results may be difficult. However, the increasing of computers performances allows management of very large point clouds, and helps discover interesting perspectives for the utilization of 3D models.

3D Laser scanner should be considered as one of the most effective instrument for monitoring (3D monitoring).The availability of the scanned information such as intensity and color values, would make a further study to measure the crack propagation and detect the potential structure weakness of a building.

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