PROCESSING, ANALYSIS AND INTERPRETATION SOFTWARES USED FOR LASER SCANNING. COMPARATIVE STUDY

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Abstract: *The Processing of measurements obtained from laser scanning is difficult given the multitude of points determined, it involves several steps: registration, point cloud processing, post-processing, 2D and 3D modeling and making the final products. Each manufacturer of terrestrial laser scanning systems developed one or more data processing programs which have largely the same characteristics, differences occur depending on the features works for which they were created.*

Key-Words: *Laser scanning systems, software processing*

1. Introduction

Processing measurements obtained from laser scanning involves several steps: registration, point cloud processing, post-processing, 2D and 3D modeling and making the final products. Each manufacturer of terrestrial laser scanning systems developed one or more data processing programs which have largely the same characteristics, differences occur depending on the specific work for which they were created.
Software packages developed for processing information taken with laser scanning systems can be divided into two categories:

- ✓ software packages used for static scanning systems - include registering and interpreting modules. Examples: **SceneVision-3D**, poduced by **3rdTech Inc.**, **Bentley CloudWorx**, produced by **Bentley Systems Inc.**, **Faro Scene**, produced by **Faro Technologies**, **I-SiTE Studio** produced by **I-SiTE**, **Leica Cyclone** produced by **Leica**, **RiSCAN PRO** and **Phidias** produced by **Riegl, RealWorks Survey** produced by **Trimble Navigation**, **LFM Modeller** produced by **Z + F**;
- ✓ software packages used for dynamic scanning systems - in addition to registering and interpretation modules have to contain the modules for processing GPS position information and information from inertial platform. Examples: **I-SiTE Studio** produced by **I-SiTE**, **RiSCAN PRO** and **Phidias** produced by **Riegl**, **RealWorks Survey** produced by **Trimble Navigation** ;

2. SceneVision-3D

SceneVision-3D is software for controlling the scanning and modeling data for both beginners and experienced users. The software combines intuitive navigation in model with a wide range of views, modeling and analysis functions.

Obtaining a complete scene or object often requires scanning several locations in order to see all sides of an object or objects located "behind" other objects, SceneVision provide functions that allow quick and easy alignment of scans to produce a single model.

The same features also allow referencing digital photos taken by the scanning system, for better analysis and interpretation of the model obtained after scanning.

SceneVision is much more than a tool for data visualization and three-dimensional modeling, offering simple features, rapid measurement of distances between points in the model, the perpendicular distances, angle measurements, determining intersections of lines and surfaces. It can also create very easily dimensioned plans and sections with routine SceneVision-3D Wall Wizard (Figure 1).

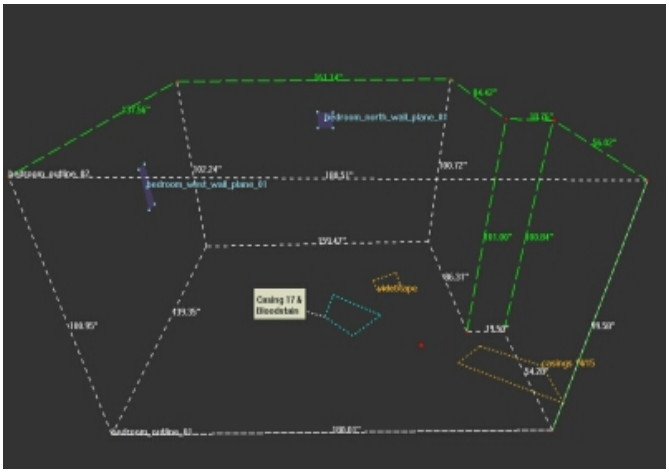

Figure 1 – Mapping room

SceneVision go a step further by offering specific functions for analysis applications, especially in the field of forensic scans. For example, if scanning a crime scene, software provides modules that can analyze, calculate and display trajectories of blood splashes or bullet marks based on traces and on walls and the victim position, offering various possibilities of interpretation (Figure 2).

The software allows export and import in different formats, allowing the use of 3D models obtained for animation, simulation and CAD software.

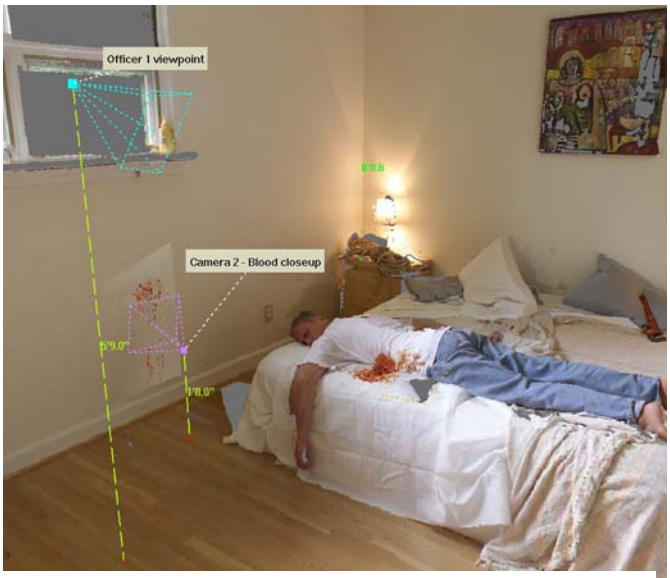

Figure 2 - Forensic analysis

SceneVision-3D is used successfully in various fields such as mechanical engineering, aerospace, cadastre, complete measurements and reconstructions forensic at a crime scene or accident scene, to create detailed 3D scenes for graphic applications in virtual reality, special effects for film and computer games.

3. FARO Scene

FARO Scene is a high performance software for proper modeling 3D point clouds resulting from the scans, recommended for experienced users.

It is designed for viewing, managing and working on 3D high resolution scanning systems produced by FARO, enabling the user to manipulate the scan tool and then providing functions of registering and analysis of point clouds, 3D visualization and creation of objects. Analysis of 3D point cloud with FARO Scene software makes it possible to obtain information such as: measuring distances between points and objects, calculation of areas and volumes, special functions also allow the user to examine elevations and display the results in a wide range of colors.

Figure 3 - Scanning tunnels

FARO Scene offers besides registration on at least three common points used by all software, a new referenced scans facility called "Cluster Registration" with which it can define and create reference points directly from scanned targets when scanning. With this method is very easy to solve problems in registering confined spaces, where the software has to use many common constraint points, that normally conduct in a reduced accuracy.

Another important feature of the FARO Scene software is that it can improve the quality of scanned data using the procedure "Noise Compression", this feature reduces data file size without loss of detail. "Noise Compression" can be applied both during the effective scanning by setting the control scan parameters and post-scan processing.

Import and export data can be accomplish in various formats: georeferenced and registering control points (*. cor, *. csv), scanned points (FaroScan FARO, FaroCloud, *. dxf, *. vrlm, *. igs, *. txt, *. xyz *. pts, *. ptx, *. ptc, *. ptz), import digital pictures (*. jpg, *. png, *. bmp), export panoramic images (*. jpg), transfer data (transfer from FARO Cloud for AutoCAD)

FARO Scene offers special modules for applications in:

- ✓ Architecture (FARO Architecture Package with Architectural Desktop) design (Packaged with GEOMAG FARO Design Studio) specifically for automotive;
- ✓ Restoration of heritage objects and objectives and monuments (FARO Heritage Package)
- ✓ Tunnels (FARO Tunnel Package). Give users a powerful tool to control tunnels of all shapes, with unlimited opportunities. Tunnels can design or highlight real profile resulting from scanning. 3D data can be viewed individually or longitudinal and transversal cross sections; it can perform calculations of volume or embankments. Also it can show, in real time to a theoretical model for a quick check of the tunnel pieces, direct comparisons of sections, distances.
- ✓ energy transmission lines, telecommunications, pipelines (FARO Process, Power & Piping)

4. I-SiTE Studio

I-Site Studio software is the first point cloud processing product for Windows 64 bit platform. The software can manage projects and scans hundreds of millions of points easily, large datasets can be efficiently interrogated, modeled and manipulated on a desktop or laptop PC, transfer data between projects is easy and fast.
I-Site Studio integrates and manages data scanned with different scanning systems (I-Site, Leica, Optech). It has a powerful graphical interface that allows 3D modeling for: mining (quarries), surveying and mapping applications, communication routes (road and rail). The software is structured in modules focused on different areas of activity and performance of specific applications:

- ✓ volume calculation (Maptek I-SiTE) offers an ideal solution for measuring outside and inside stocks, because it allows a very detailed model to calculate precise volumes. In the case of harmful and hazardous materials inventory, where is no possibility to scan the upper surfaces of the land stock for volume calculation, the program offers the option of combining ground scans with air scans.

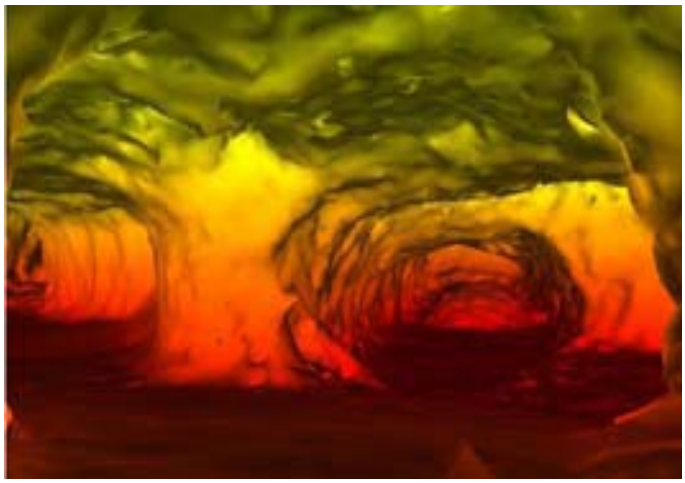

Figura 4 - Underground scans

- ✓ Military operations, police, forensic (I-Site Forensic).
- ✓ Underground mining galleries scans, tunnels (I-Site Voidworks) Based on data collected by scan the program can determine the width, height and length of tunnels, the position of auxiliary equipment such as ventilation ducts, utility pipes and cables, it can perform sections and profiles.

5. RiSCAN PRO

Riscani PRO is project-oriented software, all data acquired during the measurement campaign are organized and stored in a single project. The software scans the data, manage and control checkpoints coordinates for the whole process of registering to transform the data of multiple scans and bring them into a single coordinate system. In addition, if the scanner is equipped with digital camera, images are obtained throughout the RiSCAN PRO.

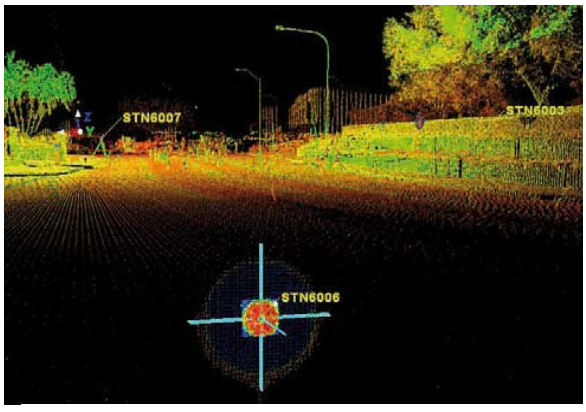

Figure 5 – Checkpoints scan

RiSCAN PRO is designed to minimize time data acquisition and processing, while providing tools for visual inspection of the data, allows automatic scanning control points (Figure 5) and incorporating in the scan data their coordinates, provides powerful post-

processing functions, the project design is based on XML protocol that allows easy access to all information.

Generally all RIEGL scanning systems provide cloud of points in own coordinate system, but RiSCAN PRO allows the user to define a global coordinate system, transformation of coordinates is made automatically based on control points. To scan the objective that need high accuracy of the transformation, it is recommended to use at least four control points, for accuracies of 2-5 cm, it can be used the instrument in combination with a GPS system and through DGPS measurements to obtain the coordinates of scanning station.

Figure 6 - View cloud of points

RiSCAN PRO offers various tools to view data and images. Data can be displayed online during acquisition, visualization, the post-scan can be 2D and 3D, with different color-coding options (takeover intensity encoding height information, RGB information), 3D visualization of clouds of points can be global or in sections, with or without pictures taken by the instrument. Initial scan data can be filtered by applying cleaning algorithms, smoothing and subsequent decimation and noise reduction, leading to reduce file size but with preservation of data accuracy.

RiSCAN PRO offers various ways to triangulate the point cloud by creating TIN (Triangulated Irregular Network), DTM (Digital Terrain Model) and DEM (Digital Elevation Model) which allows calculation of volume and surface. Mesh networks can be textured using photographs taken by the tool, for better analysis of the cloud of points and the extraction and elimination of various information (shadows, vegetation).

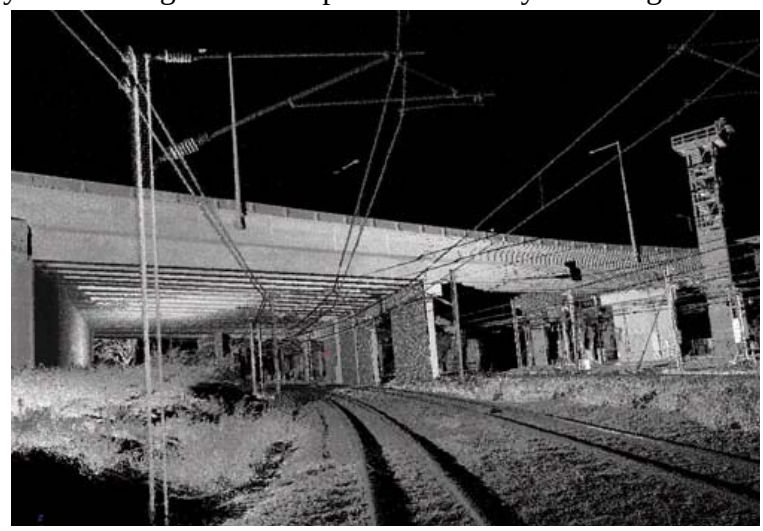

Figure 7 - Scans for communication routes

The main activities RiSCAN PRO are used, are:

- ✓ Archaeology
- ✓ Monitoring of buildings
- ✓ Routes of communication and art works (tunnels, bridges, viaducts)
- ✓ Topography
- ✓ Police - reconstruction and analysis at scenes of road accidents

6. Phidias

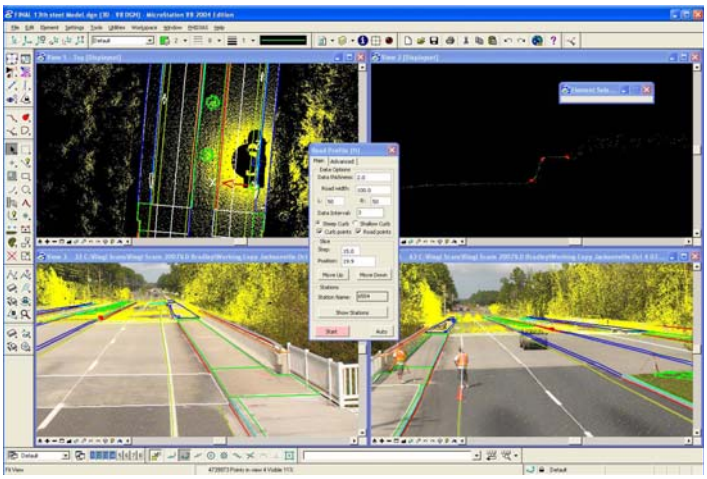

Figure 8 – Phidias module

A full exploitation of 3D information by combining digital photogrammetry with laser scanning is possible by Phidias, a software plug-in designed by MicroStation. Phidias application accepts data from both terrestrial scanning systems and the static or dynamic air systems. The software provides all necessary tools for photogrammetric evaluation combined with laser scanning data by taking advantage of all features and facilities of a 3D CAD system. Phidias allows import of the original project RiSCAN PRO, all calibration data and oriented images are taken directly, also recognizes most image formats that can also be imported into the project with reference and analyzed simultaneously.

Evaluation Phidias images, the reconstruction geometry of scanned object or found in the photos, occurs MicroStation CAD environment, (Figure 8), allowing the creation of drawings and graphics functions using MicroStation. Evaluation curved and irregular surfaces is much easier, faster and more precisely to achieve by combining information provided by the cloud of points and photos in combination with the facilities of the two software.

MANUFACTURER/DISTRIBUTOR	3rdTech Inc.	Faro Technologies	I-SiTE	Riegl USA	Riegl USA
NAME/FUNCTIONALITY OF MODULES OR COMPONENTS OF SUITE	SceneVision-3D	Faro Scene	I-SiTE Studio	RiScan Pro	Phidias
Price (list by modules or components)	Contact 3rdTech	70,000 €	$24,000	N/C	$15,000
Laser scanner brands and models from which data can be imported directly	Faro, Polhemus, Riegl.		I-SiTE, Riegl	Riegl	All
Operating systems supported (if one is preferred, please state)	Win 2000/XP	Win 2000/XP	Win X64 (pref), XP	Microsoft	MicroStation
Minimum CPU requirement	Pentium 4	1 GHz	1.8 GH		
Minimum RAM required	512 MB)	1 GB	512 MB	1024 MB	1024 MB
Space required on hard disk to properly run application, including swap space, etc. (list in Mb)	50 MB (512 MB swap)	1 GB	2 GB	5 GB	5 GB
Other hardware requirements	3D graphics card	graphics card with 32 MB and OpenGL hardware; ethernet card for licensing	128 MB graphics memory		
CLOUD EDITING/ANALYSIS					
Can features be defined with user-created code libraries?	Planes, contours,lines ,points	No	No	No	Yes
Feature codes exportable to CAD software? (specify which software)	VRML model, lines		No	No	Yes
Can user compare cloud or shapes fitted to clouds to plan,or perform theoretical shape and interference checking? (State which,all or none.)	None	Visually	All	Yes	Yes
Ability to make measurements such as distances, angles, areas, volumes, of lines, planes, shapes and other surfaces from cloud? (State which, all or none.)	Distances between points, lines, planes, perpendiculars;	Distances	All	Yes	All

	angles between lines and planes.				
Can user overlay or drape a photograph from an external source (e.g., digital camera) on cloud or elements extracted from cloud?	**Yes, FA**	**Yes**	**No**	**Yes**	**Yes**
Ability to register scans without the use of targets?	**Yes, FA**	**No**	**Yes (FA)**	**Yes**	**No**
Ability to place several clouds from different scans in coordinated 3D space using total station or GPS survey data that has been used to determine positions of scanner and alignment of scans?	**No**	**Yes**	**Yes (FA)**	**Yes**	**Yes**
Analyze points in a cloud representing shapes such as planes, cylinders and spheres to detect measurement outliers?	**Planes only**	**Yes**	**Yes (FA)**	**Yes**	**Yes**
Ability to integrate scans with floor plans, engineering drawings of objects and surveyed information? (State which, all or none.)	**None**	**All**	**All**	**No**	**All**
Automate decimation of points in selectable areas to make data files as compact as possible?	**Yes, FA**	**Yes**	**Yes (SA)**	**Yes**	**Yes**
Is fitting of lines, planes and shapes to cloud done manually or automatically, or both?	**Automatic plane fitting**	**Both**	**Both**	**Manually**	**Both**
For automatic and manual fitting,what techniques are used or available (e.g. least squares, taking average, etc.)?	**Least squares**	**Least squares**	**Least squares**	**Least squares**	**Least squares**
Ability to automatically track lines or limits of areas by color or texture discrimination?	**No**	**Yes**	**Yes (SA)**	**Yes**	**Yes**
Ability to automatically calculate and list alignment of center line of shapes (such as a pipe) containing straight and curved segments such as elbows?	**No**	**Yes**	**No**	**No**	**Yes**
Maximum number of points that can be loaded	**100 million**	**200 mil**		**No limit**	**No limit**
Automatic removal of noise (e.g., cars on road, vegetation, etc.)?	**No**	**No**	**Yes (SA)**		
RENDERING/CAD MODEL GENERATION/VIEWING					
Does software automatically or manually generate or create CAD models or model segments from point clouds and other known information? (Specify level of automation and intelligence.)	**[5]**	**Manually**	**Yes (FA)**	**No**	**Yes**
Are items (CAD models such as pipes, steel, flanges, elbow) fit to the point cloud using standard object tables/catalogs?	**No**	**No**	**No**	**No**	**Yes**
Create statistical quality assurance reports on the modeled objects?	**No**	**No**	**Yes (FA)**	**No**	**Yes**
Automatically compute, without user interaction, a full 3D polygonal mesh (not view-based) from a point cloud?	**Yes, FA**	**No**	**Yes (FA)**	**Yes**	**No**
Perform contour generation?	**No**	**No**	**Yes (FA)**	**Yes**	**Yes**
Perform volume calculation capabilities?	**No**	**No**	**Yes (FA)**	**Yes**	**Yes**
Perform solid modeling (volume generation) based on user-defined lines, planes and other surfaces as bounds?	**No**	**No**	**Yes (FA)**	**No**	**Yes**
Perform profile and cross-section generation along any cutting plane, family of planes or road alignment?	**Yes**	**Yes**	**Yes (FA)**	**Yes**	**Yes**
Have edge detection technology to determine boundaries of solids, planes and other shapes?	**No**	**Yes**	**Yes (FA)**	**Yes**	**Yes**
Perform automatic extraction of standard shapes from cloud (e.g. pipe fittings, structural steel members, etc.)?	**No**	**No**	**No**	**No**	**Yes**
Can user view cloud or generated shapes or models from any viewpoint in 3D?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Are fly-throughs or walk-throughs supported?	**Yes**	**Yes**	**Yes (SA)**	**Yes**	**Yes**
Have intelligent display of detail depending on scale of the view?	**No**	**No**	**Not required**	**Yes**	**Yes**
Can user select transparent/opaque surface for cloud and CAD shapes?	**Yes**	**Yes**	**Yes**	**No**	**Yes**
Which export formats are supported?	**RTPI,VRML, ASCI XYZ, PIF**	**VRML,DXF, XYZ text, XYZ binary, IGES, PTS, PTX, PTC**	**3DP, DXF, DGN,DWG, OBJ, MA,VRML, txt, avi**	**Multiple**	**Multiple**

Specify other measurement tools (e.g., clearance, cut/fill, table of elevation differences)	**Perpendicular point to plane**	**Point to point, object to object**	**Yes (SA)**	**Multiple**	**Multiple**
Can the pointcloud be rendered with visualization effects (e.g., intensity mapping, elevation mapping, shading, silhouette)?	**Yes Laser intensity, range, full color.**	**No**	**Yes**	**Yes**	**Yes**
Can the software automatically detect scan targets?	**No**	**No**	**Yes (FA)**	**Yes**	**No**
MISCELLANEOUS					
Provide high-speed thumbnail views of scans, clouds, photographic images and generated shapes?	**No**	**Yes**	**No**	**Yes**	**Yes**
Can client/server system support multiple users?	**No**	**N/A**	**Yes**	**Yes**	**No**
Is client/server system supported to enable several clients contributing to a single project?	**No**	**N/A**	**Yes**	**Yes**	**Yes**

7. Conclusions

The new laser scanning technology have revolutionized the measurement technique even in engineering topography, can be successfully used for the measurements to modernize tunnels, their use brings significant benefits both in terms of technical and economic.

Processing software of laser scanning measurements are made up of several methods of adjustment and registration, this enables the user to choose the appropriate method of processing according to the characteristics of the performed study. Reports can be analyzed, compared and evaluated for statistical purposes.

Management software for registration and processing provides a wide range of possibilities for the export and import data in various formats. This allows to use the resulting products from scanning in other software for various applications, especially for modeling and rendering applications. The most formats used for export and import are from dedicated software such as AutoCAD, 3D Studio Max, Adobe Photoshop, Corel Draw.

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