SURVEY APPLICATIONS USING THE OPTECH ILRIS 3D LASER SCANNER AND PHOTOGRAMMETRY FOR A COMPLETE DETAILED 3D CAD RECONSTRUCTION OF OBJECTS

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1 - INTRODUCTION

Terrestrial Laser Scanner is a key methodology in cultural heritage survey, as it allows the representation of objects with high accuracy from the geometric point of view but also allows the generation of graphic representations of high visual impact for public (non technical) audience.

For the survey of monumental structures, for which it is difficult to have contact with the object because of the operating context or because of its valuable features, there are two leading techniques: the photogrammetric survey and the laser scanner techniques.

This paper will discuss two case studies:

The first case study is Vittone's chapel, which is located in Carignano (Turin Province) Italy. It is characterized by a complex internal structure as a result of multiple layers of arches and other structures. The role of these features is not only structural but also figurative in order to represent, in the Chapel, the different levels of celestial hierarchy.

The Chapel is now involved in a documentation project and thanks to the presence of scaffolding structures different scans have been carried out with an Optech ILRIS 3D instrument. At the same time, different photos of the building have been taken using a calibrated digital camera.

Fig 1 - View of the Church from the top

The second case study is a survey of an Aluminium Refinery in the Republic of Guiana. The Refinery belongs to RUSAL, a Russian company and they required a complete 3D survey and CAD drawing of the entire area.

The work has been carried out integrating the use of a laser scanner with topographical instrumentation and GPS. Due to the complexity of the geometry, many scans have been taken along the entire Refinery territory.

The result has been the 3D modeling of the engineer installation and production equipment and the 2D design of the structures that have to be rebuilt.

Fig 2 - View of a part of the refinery during the survey

2 – STUDY CASE 1
SURVEY OF THE VITTONE'S SANCTUARY USING LASER SCANNER AND PHOTOGRAMMETRY

The Vittone's sanctuary or Cappella della Visitazione at Vallinotto (1738-1739), located in the Carignano (Turin Province, NW Italy), was erected for agricultural workers of the town. The church is characterized by a very complex internal structure. The role of these features is not only structural but also figurative in order to represent, in the Chapel, the different levels of celestial hierarchy (Fig 3).

The Church has an elegant shape and it is a baroque masterpiece of art. It has been made more precious with its Rococo internal decorations.

Fig 3 - The spectacular dome from the inside

2.1 THE SURVEY

The survey of the church was carried out over 3 days using the ILRIS 3D Optech laser scanner.

Scans were accomplished at three different levels, thanks to various scaffolding heights, (10 m, 6 m and ground) in order to obtain a complete survey of the inside of the building (Fig 4 and 5).

This was the most complex part of the survey due to the complex morphology of the structure.

Many scans were done for every session changing the position and orientation of the sensor in order to reduce the shadow areas.

The ILRIS was operated using a wireless connection (no people) to avoid any vibration of the scaffolding to ensure the best accuracy from every measurement.

Fig 4 - Image during the survey

Fig 5 - Scheme of the scaffoldings and the survey levels

A second series of scans were made in order to measure the exterior part of the structure. The ILRIS was positioned in different locations in order to get the complete survey of the building.

At the same time a classical topographical survey was performed, using a no prism Sokkia total station. This was done in order to measure tie points so that it could be used to merge the internal and external scans and to assess the alignment phase's accuracy.

The final model was processed in order to project calibrated images on some test areas through ortho-image generation.

Afterward, the altar was scanned with a further topographical survey in order to check the laser scanner accuracy. For this test, some retro-reflective targets were positioned and measured both with the ILRIS and with and the Sokkia total station.

During the second day, some photos were collected using a calibrated camera to be used for photogrammetric application.

2.2 DATA PROCESSING

Regarding the processing and the modelling of the laser scanner data, every scan has its own reference system relative to the survey location, therefore the creation of the solid model is dependent on the merging of all the scans made in different positions using only one reference system. The software used for this application and for processing the data is the module IMAlign by PolyWorks (http://www.innovmetric.com); this software allows you to chose some natural point for linking up different scans (such as some recognizable feature on the object surveyed, corners, identifiable geometry, different reflectivity of the walls, etc) (Fig 6).

The entire procedure makes the survey easier while in the field and at the same time makes it faster because of the absence of the artificial targets, used only for the geo-reference of the entire model. The alignment of different scans is made individualizing three or more connection points present on both of the two adjacent scans. These points, the position of which is known in their respective reference systems, at the beginning, consent to move closer the two scans; the software, that uses ICP algorithm, realises subsequently an automatic research of the "homologue" points, performing a spatial rotation and translation without scale variation in respect to the reference system of the adjacent scan and it estimates the 6 independent parameters: the 3 rotation around the axis XYZ and the 3 spatial translation.

In this way with the alignment it has been given the parameters estimation of the orientation and generated a roto-translation matrix for each scan. This process was applied on each scan and permited the creation of the complete solid model of the object surveyed.

At the end of this process, a triangulation (TIN) was realized and the model was geo-referenced using the ground control points measured by the total station.

Once the spatial position of at least one of these three targets is known, it is possible to roto-translate the entire model and geo-reference each point of the scan.

In some areas some photos were projected using the "camera calibration" tool of JRC Reconstructor.

Due to the complexity of the structure, we had some issues texturing the dome and the arches. It was difficult in these areas to determine the right view of where to project the images.

The use of the "Virtual Scan" tool (Sgrenzaroli, Vassena, 2007) of the Reconstructor helped to solve the problem of generating new surfaces, congruent with the original reference system, but oriented towards the photo projection (Fig 7).
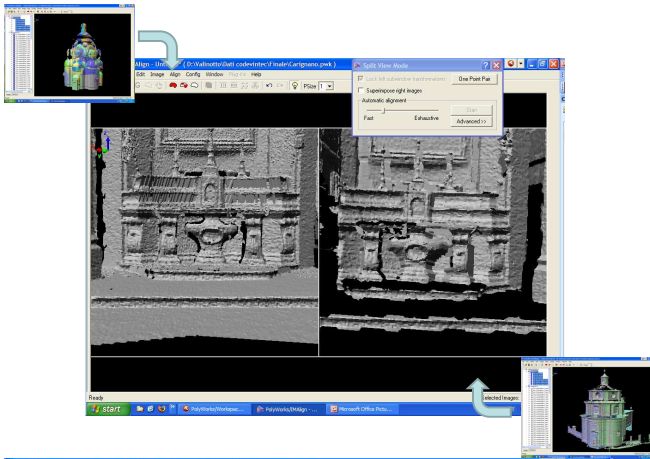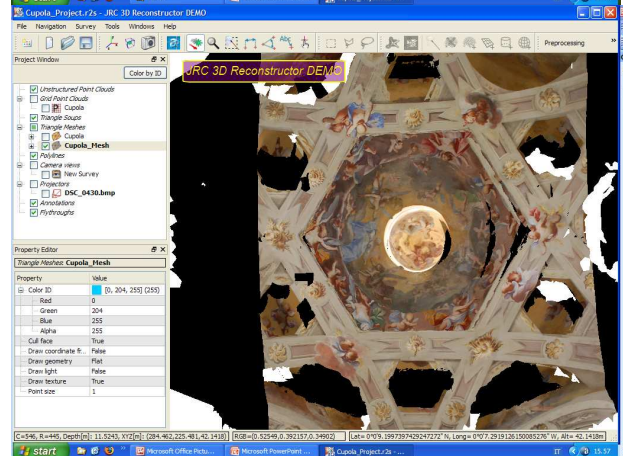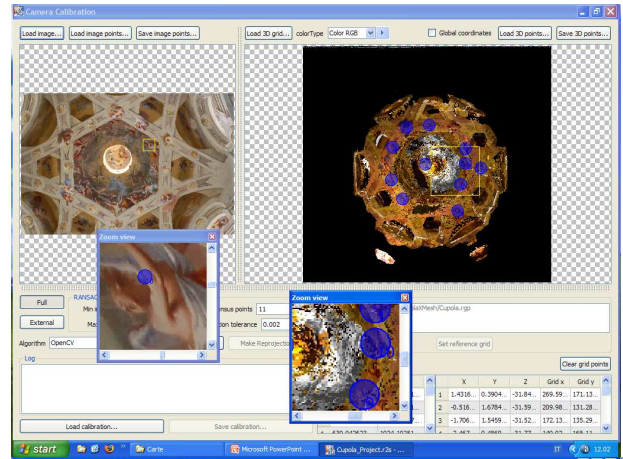
Fig 6 - Alignment of the Altar

Fig 7 - Example of projection of images over the 3D model

2.3 RESULTS

The result is the creation of the triangulated 3D model of the entire church. The use of the ICP algorithm (Beinat, 2006; Besl, Mc Kay, 1992; Chen, Medioni, 1992) secured both at the beginning and after during the alignment resulted in very good accuracy.

Name	Avarage (m)		Std Dev (m)
Im 1	0.0018	0.0051	
Im 2	0.0018	0.0041	
Im 3	-0.0038	0.0048	
Im 4	-0.0013	0.0042	

A further confirmation of the quality of the model comes from the comparison of the targets: this test confirmed the absence of differences between the average = 0.0020 and the standard deviation = 0.0093 obtained from the two tests (total station and laser scanner)

The projection of the calibrated images allowed the reconstruction of important portions of the building, increasing the culture heritage value.

3 - CASE STUDY 2
SURVEY OF THE "RUSAL" REFINERY

The Alumina Refinery "Friguia" was built by the French Company Pechiney in the 1959. Between 1959 and 2006, the refinery changed owners several times and was finally purchased by the Russian RUSAL in 2002.

In April 2006, RUSAL and the Government of Guiana reached an agreement for the privatization of the refinery. The estimated capacity of this refinery is 640,000 tonnes of alumina and 2.5 mln tonnes of bauxite per annum.

Friguia refinery is one of the largest employers in Guinea with 1,102 employees. The volume of bauxite reserves under exploration has reached 35 mln tonnes; the volume of the explored resources is 361 mln tonnes. The refinery's infrastructure includes a 160 km long railway network used for transportation of products, raw materials and fuel.

RUSAL is the world's largest aluminium company and it accounts for 12.5% of the entire global output of primary aluminium and 16% of worldwide aluminium production.

Fig 8 - Image of the refinery

Fig 10 - Final point cloud

3.1 SURVEY AND DATA PROCESSING

The required work was to upgrade the original old refinery drawing and in particular:
- Topographic survey of the entire refinery territory (85 hectares). Drawing in scale 1:500;
- Topographic survey of the sludge depository (200 hectares). Drawing in scale 2:2000;
- 3D modelling of the engineer installation and production equipment;
- 2D design of the technical equipment that needs to be rebuild.

The entire survey was carried out using the ILRIS 3D and the Faro laser scanners. A total of 500 scans were collected for a total of 250 million points.
The ILRIS 3D laser scanner was used for Topographical plan creation and external 3D survey.
The commercial software PolyWorks was used for data processing using a 64 bit computer with 16GB of RAM.
The alignment of the different scans was done using the module IMAlign as explained at the chapter 2.2 (Fig 9).

3.2 RESULTS

The result is the creation of the geo-referenced triangulated 3D model of the entire Refinery (Fig 11).
The error in the alignment is almost nil, due to the high quality of the PolyWorks alignment tool. Also the Geo-Referenciation was very good using the spheres.

The total processing required almost 3 months with a single operator, mainly for the CAD reconstruction subdivided in this way:
- Topographical survey 1:500 (85 hectares): 1 month in the field and 1 month in the office.
- Topographical survey 1:2000 (200 hectares): 3 days in the field and 7 days in the office
- 3D modelling: 1 month in the filed and 3 days in the office
- 2D design creation: 3 days
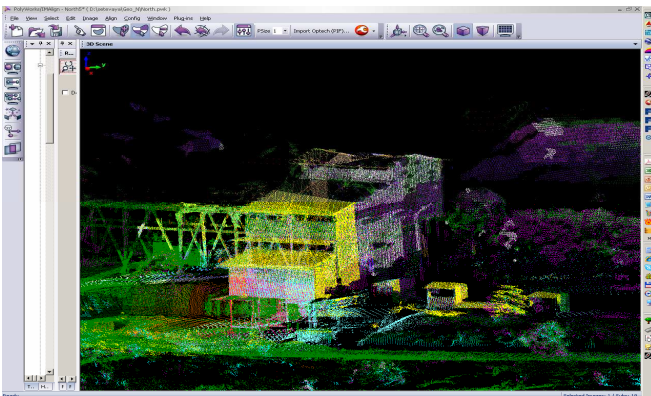

Fig 11 - Complete 3D modelling

Fig 9 - Image during the alignment

The final point cloud was geo-referenced using 14 topographical ground control points measured with a GPS. Some spheres were used to increase the accuracy (Fig 10).
The final point cloud was sub divided in different projects and imported in Autodesk AutoCAD with the Kubit for the final rendering.
100.000 primitives were created and generate the final 3D output (Fig 12 and 13).
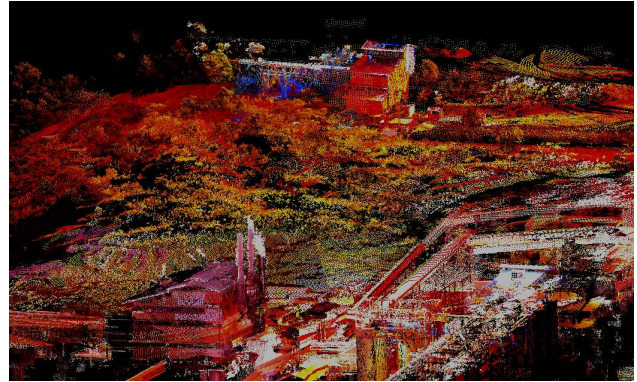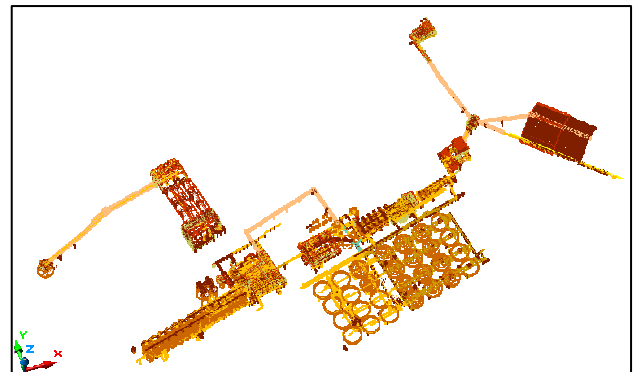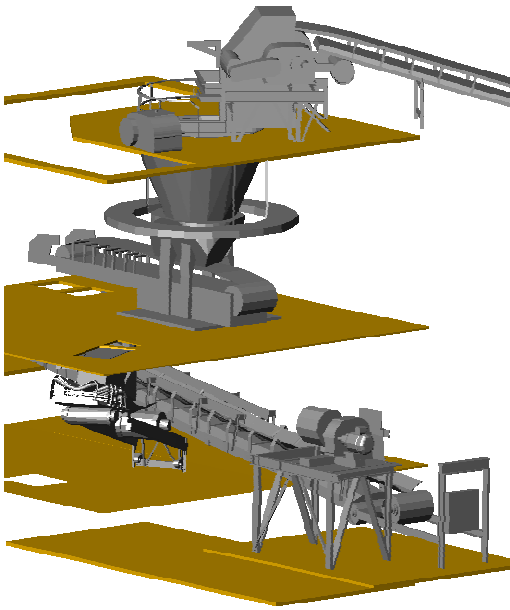

Fig 12 - 3D CAD reconstruction

Fig 13 - 3D CAD reconstruction

REFERENCES

Beinat A. (2006) "Tecniche di registrazione", in Crosilla F. e
Dequal S. (a cura di), Laser Scanning Terrestre, Collana di
Geodesia e Cartografia, 008, International Centre for
Mechanical Sciences, Udine, 39-53.

Besl P. J., Mc Kay N. D. (1992) A method for registration of
3D shapes, IEEE Transactions on Pattern Analysis and Machine
Intelligence, 14 (2), 239-256.

Brinckmann A. E. (1931) Theatrum Novum Pedemontii: Ideen,
Entwürfe und Bauten von Guarini, Juvarra, Vittone vie anderen
bedeutenden Architekten des piemontesischen Hochbarocks,
Düsseldorf, 96.

Chen Y., Medioni G. G. (1992) Object Modelling by
Registration of Multiple Range Images Image and Vision
Computing, 10 (3), 145-155.

Optech, ILRIS-3D, Technical Specifications;
http://www.optech.ca/i3dtechoverview-ilris.htm

Pommer R. (1966) Eighteenth - Century Architecture in
Piedmont: The Open Structures of Juvarra, Alfieri and Vittone
New York University Press and University of London Press,
New York and London, 300 pp.

Portoghesi P. (1982) L'angelo della storia. Teoria e linguaggi
dell'architettura, Editrice Laterza, 96 pp.

Wittkower R. (1958) Art and Architecture in Italy: 1600-1750
Penguin books, the Pelican History of Art Series, 428 pp.

Sgrenzaroli M., Vassena G. (2007) "L'approccio Virtual Scan"
in Tecniche di rilevamento tridimensionale tramite laser scanner
Volume 1 - Introduzione generale, Starrylink Editrice, Brescia,
74-79.