3D LASER SCANNER VERSUS NEW SELF-MODELLING PHOTOGRAMMETRY SOLUTIONS. APLICATIONS IN ARCHITECTURE AND ARCHAEOLOGY.

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ABSTRACT

As a consequence of the latest years advances, both in hardware and software, several applications in photogrammetry have been released into the market. This is of a great interest in the architectural sector, mainly for documentation purposes in the fields of heritage as well as in restoration and rehabilitation.

With just a conventional PC, we will be able to obtain a semi-automatic solid model, via stereoscopic pairs, using the latest versions of these performant applications. Thus we can get a three dimensional model of an object in very short time with very little investment.

On the other hand, due to the progressive advances in the three dimensional laser-scanner technologies, the scanners are used more and more often in architectural and archaeological geometric survey works.

However, given the fact that both technologies (laser-scanner and the new versions of photogrammetry software), are so new, it does not exist clear decision criteria when it comes to decide which is the best one to use in each case of study.

In this paper we show a comparison between two different commercial solutions that appeared recently in the market. Both of them are able to do the survey and representation of complex objects and irregular geometries, obtaining mapped three dimensional models, and carrying out a comprehensive study about the process, efficiency and production costs in each case.

1.- The case of study

The case of study showed in this paper is the different building in Granada, especially in Darro road facades

1.1.- Brief historic review

One of the oldest and most picturesque streets of Granada. It follows the right bank of the Darro and was depicted and sketched by many artists and romantic travellers. In the Muslim era there was a wall along the river. Since the 16th century, the wealthy families of the city start building their palatial houses, like the Condes de Arco house. They were probably attracted by the healthy environment. In 1609 the lands donated by the Lords of Castril at the end of the 'Calle Darro' were transformed in a large avenue for the people of the city. The reform of the urban space in the 17th century is accentuated by the 'Carrera del Darro', also known as 'de los Tristes'. After the explosion of a powder magazine next to the 'San Pedro' church, the course of the river was changed and the street was widened. A new course is created; one recognizable by the old palatial houses facing the river.

2.- Work flow proposal.

The aim of this study is to compare two different commercial solutions that appeared recently in the market, both of which can survey and represent complex objects and irregular geometries, obtaining mapped 3D models. This includes a comprehensive study of the process, efficiency and production costs in each case. As a case study we have chosen a part of Granada with exceptional characteristics for this purpose.

Progress in recent years in both hardware and software has led to the release of several photogrammetry applications onto the market. This is of particular interest in the architectural sector, mainly for documentation purposes in heritage field, as well as in restoration and rehabilitation. Likewise, progress in three dimensional laser-scanner technology has meant that scanners are being increasingly used in architectural and archaeological geometric surveys [1].

Given that both technologies (laser-scanner and the new versions of photogrammetry software) are so new, there are no clear decision criteria on which is best for each particular case. The aim of this paper, therefore, is to determine parameters and features for both metric survey techniques, beginning with photogrammetry and followed by laser scanning.

3.- Geometric Data Acquisition Technologies.

3.1.- Photogrammetric technique

The "Image Master-Pro" photogrammetry programme permits the semi-automatic generation of three-dimensional models based on stereoscopic pairs made with conventional digital cameras. Very precise metric models are obtained using close-up lens photograms, which are ideal for architecture and archaeology.

The 3-D model is completely metrical, producing different views – plans, elevations, cross sections, perspectives, etc. – as well as plans with level curves and orthophotographs.

The programme's ease of use means it can be used by non-specialized operators. The only requirements are knowledge of the basic concepts of photgrammetry and some basic ideas of photography.

The stages of photogrammetric study are as follows:

3.1.1.- Field work:

3.1.1.1.- Taking photograms:

- Any camera can be used that has previously been calibrated using the programme itself.

- The higher the pixel resolution of the image, the higher the precision.

- Maximum use should be made of image resolution, using its surface as much as possible to obtain a larger scale model.

- It is most advisable for the photographs to be taken as perpendicular to the model as possible.

- The photograms to be used in making up the stereoscopic pairs should overlap by at least 60%, considering that the baseline-distance ratio should be between 1/5 and 1/10.

3.1.1.2.- Taking reference points.

The points to be measured should be perfectly recognisable in both photograms of a pair.

At least three common points are required in both photographs, with three other similar points for the correct orientation of the model. It is recommendable to take a higher number of points in order to avoid future errors of interpretation or visibility.

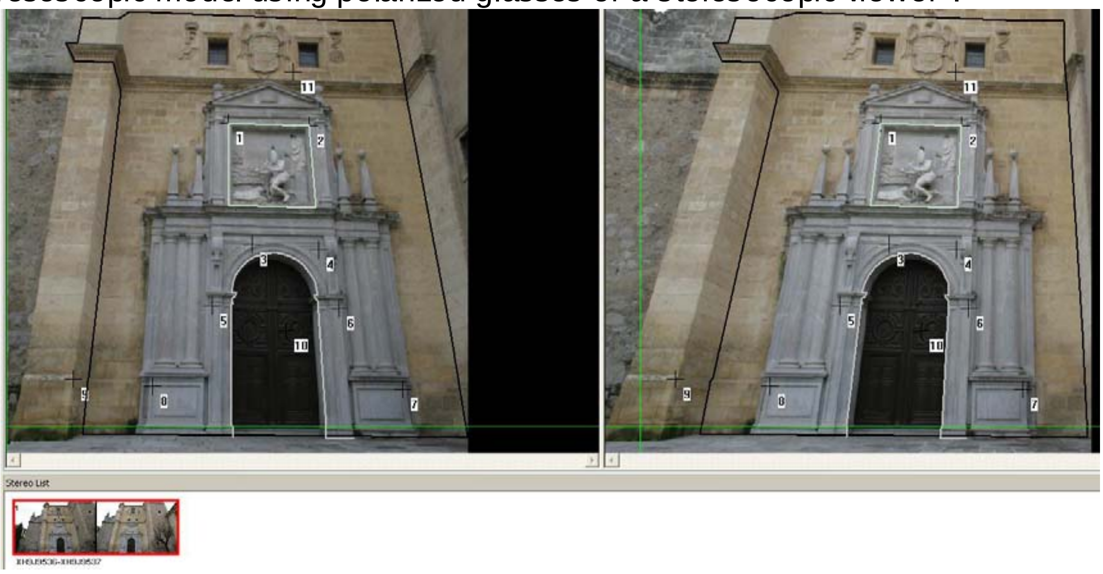
It is recommendable for the points to cover most of the photogram.

3.1.2.- Studio work

Three-dimensional measurement on the stereoscopic model requires the following stages to be carried out in advance.

3.1.2.1.- Orientation and scale setting of the stereoscopic model

Using the reference points taken in the field, the photograms are placed in the same relative position they had in the field, allowing a 3D view onscreen of the steresoscopic model using polarized glasses or a steresocopic viewer*.



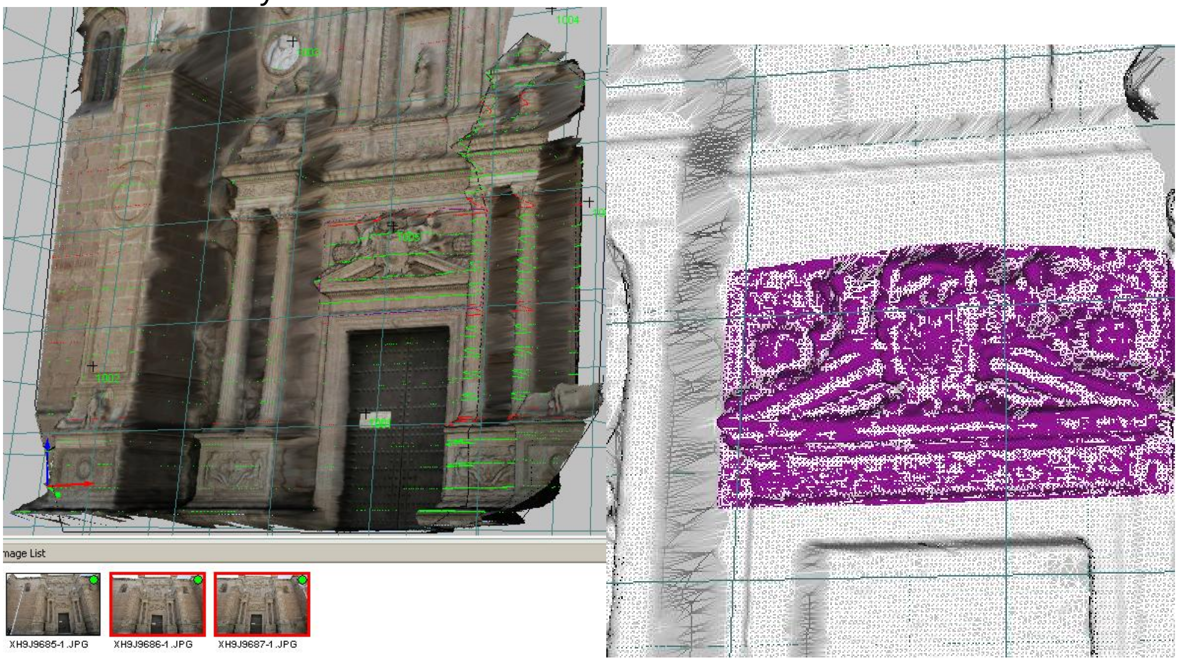
(fig 1.) Stereoscopic pair of the Monastery- Church of St. Jerome with definition of the control points and some alignments drawing.

3.1.2.2.- Restitution.

Digitalizing of single elements (alignments, pathologies, etc.).
The 3D viewing of the metrical model permits restitution (drawing) using 3D lines of all the single elements considered of interest (architectonic elements, pathologies, etc.).

3.1.2.3.- Three-dimensional modelling with different resolutions depending on the area of the model.

The programme has a powerful tool allowing automatic generation of a 3D model with the desired resolution for each zone of the model, using automatic recognition of similar pixels in both photograms. Any small anomalies occurring must be corrected manually.

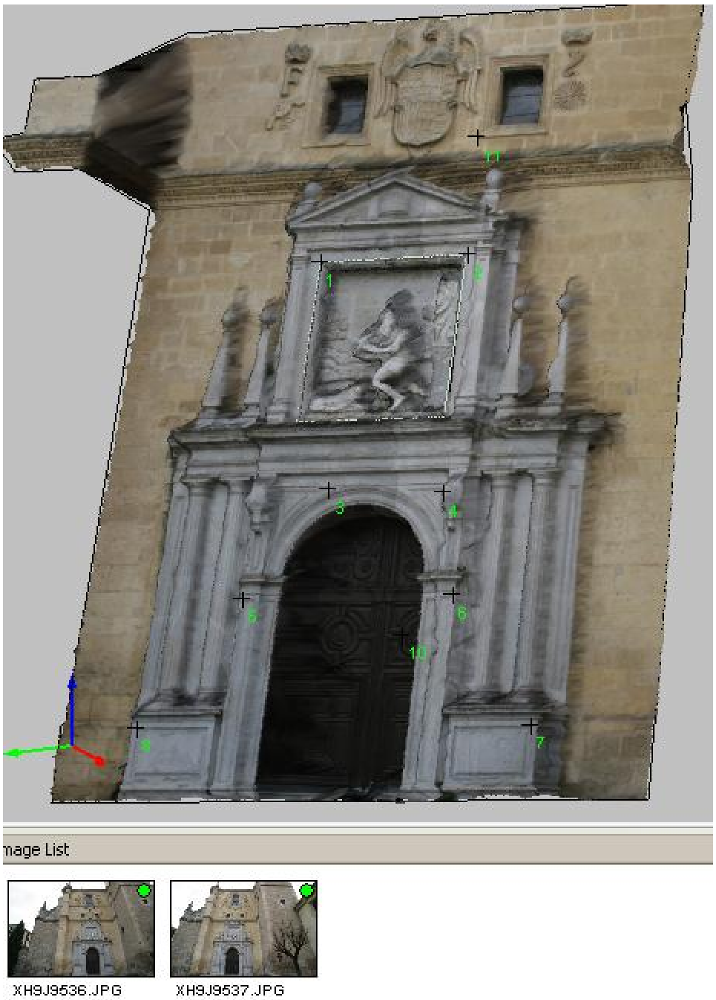


(fig 2.) 3D model of the main door. Almeria's Cathedral. Image of different resolution 3D mesh.

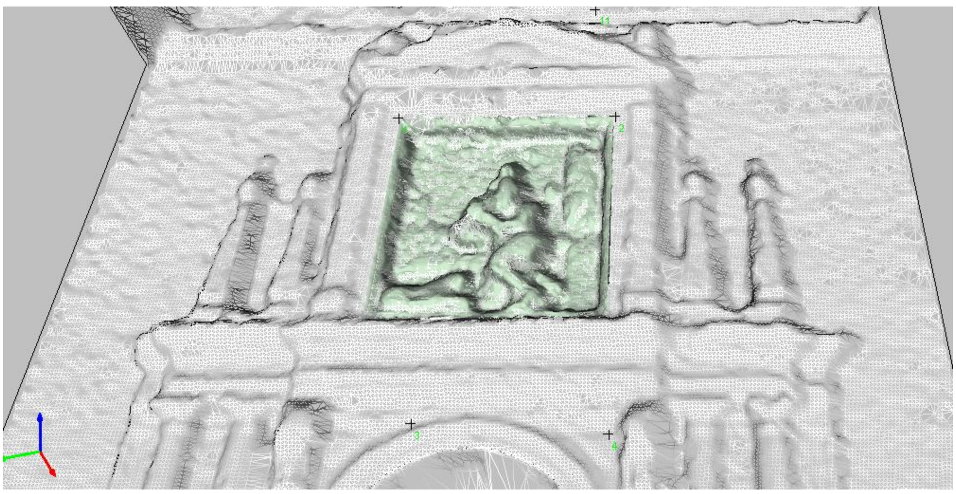
(fig 3.) Texture 3D model of sculptural detail of the main door. Almeria's Cathedral

3.1.2.3.- Data export to more conventional formats.

For these documents to be distributed and used they must be exported to more conventional formats, such as Vrml, Dxf, Tin, etc., allowing not only viewing but also manipulation of their data.



(fig 4) 3D model of monastery-Church of S. Jerónimo (Granada)



(fig. 6) Model 3D of Plateresque façade. Lord of Castril House. – Actual Archeological Museum of Granada

(fig. 7.1) Detail model 3D of façade. Castril house.

(fig 7.2 Ortho-image)

3.2.- Laser scanning technology.

Three-dimensional laser scanners are gradually becoming a tool that allows degrees of precision and acquisition speed unheard of until only a few years ago [4] [5]. One of the best laser scanning systems is manufactured by Riegl laser measurement systems. We have used a *RIEGL* LMS-Z420i terrestrial laser scanner system. This consists of a high performance long-range 3D scanner, the associated RiSCAN PRO operating and processing software, and a calibrated and accurately orientated and mounted high-resolution digital camera.

The system provides data which lends itself to automatic or semi-automatic processing of scan and image data to generate products such as textured TIN surfaces or orthophotos with depth information.

3.2.1.- Laser scanning survey performance

The collection of 3D coordinates of millions of points over an object surface in a few minutes represents a powerful tool to survey the architectonic heritage, where geometric precision and photorealistic details are essential [2].

This laser scanner uses the Time of fly system to acquire a large amount of metric data in a short period of time. Data acquisition also takes place in “real time”. Both range and speed make laser scanners a very suitable technique for surveying heritage features.

The *RIEGL* LMS-Z420i is a sensor specially designed for the rapid acquisition of high-quality three dimensional images, providing a unique and unrivalled combination of a wide field-of-view, high maximum range, and fast data acquisition.

The bundled software package RiSCAN PRO works on a standard Windows notebook, enabling instant acquisition of high-quality 3D data in the field and providing a variety of registration, post processing and export functions. Nevertheless it is necessary to use additional software in order to obtain elaborated products and quality graphic layouts.

3.2.2.- Technical characteristics

Its specific characteristics are:
Class A laser, range up to 100m.
Measurement rate up to 11000 points per second.
Field of view: 80º vertical and 360º horizontal
Angular resolution: vertical 0.002°, horizontal 0.0025°.
Angle step-width: vertical 0.004° to 0.2°, horizontal 0.004° to 0.75°.
Weight: scanner unit 27kg (16 kg), tripod 13 kg, transport case 4 kg. (RIEGL, 2008)
Digital camera: Nikon D200. Resolution 10,2 million pixels.

3.2.3.- Data acquisition

Before using the laser scanner equipment we designed a work plan. For this it is very important to have available graphic documentation of the scanning area in order to plan the different locations of the scanner and thus optimize the number of scan positions.

Registration of the different scan positions should be made using flat reflecting targets 5 cm or 10 cm in diameter located on different planes, with minimum of three common targets for different scans. However, we chose to make the registration by means of common areas of different point clouds using the Riscan Pro software. The resolution of general scans was 0,5 cm .

However, in order to level the point cloud we had to locate more than three tie points and we have taken its 3D Universe Transverse Mercator coordinates (UTM) by means of a GPS.

3.2.4.- Data processing

When the field work was completed, the first step was to perform registration of the different scans. Registration is the process of integrating the different scan positions into a single coordinate system as a registered gobal point cloud. This integration is derived by a system of constraints, which are pairs of equivalent or overlapping objects found in two scans. The registration process computes the optimal overall alignment transformations for each component point cloud in the Registration, so that the constraints are matched as closely as possible.

The next step was to translate and rotate the registered global point cloud in order to match it into the project coordinate system by means of the target's coordinate data provided by the total station.

After registration, many points not belonging to the model were deleted and the point clouds filtered in order to obtain point clouds with a regular density of points. Furthermore, the point cloud was subjected to an iterative filter process in order to allow us to make a triangulated irregular network and obtain solid 3D models and textured with the images.

Finally, based on this model we can obtain quite a lot of sections, perspectives, orthophotos.

3.2.5. Results

(fig 8.) 3D Image generate of scanner. Castril House. Darro Road (Granada)

(fig. 9) Other view of the same façade. Castril House. This Renaissance palatial house was built in the 16th century for the Lord of Castril. Note the Plateresque façade and the balcony. The exterior façade shows its owner's power with all the heraldry iconography and images.

(fig. 10) Other view of 3D point clound models.

(fig. 11) Other view of 3D TIN models.

3.3.- Comparative table of both methodologies.

CHARACTERISTIC	PHOTOGRAMMETRY	SCANNER
Method	-Indirect measurement on stereoscopic models consisting of pairs of photographs. -Beam adjustment by recognition of similar points on the two photograms.	Direct laser measurement of real objects. -Indiscriminate measurement of points (approx. 20,000 pts/sg)
Operator's technical requirements	No complex technical requirements needed. Short operator training time (2 days).	Requires highly specialized operators. Highly complex and expensive programmes and concepts are used.
Equipment	Photographic camera (0.3 - 1 kg.) Complete station: non-prismatic measuring (3 kg.) Trípod. (5 kg.)	Scanner with case approx. 25 kg. Camera with support elements 4 kg. Tripod 4 kg. Lap-top computer 2 kg. Batteries, cables, accessories 5kg.
Team	1 operator	2 operators at least in the field.
Costs	Total station 8000 to 12,000 € Camera 300 to 6000€ Software 3000 € Total ... 11,000 to 21,000€	Variable according to brand and field of application between 60,000 and 150,000€.
Field of application	Close-up architectonic and archaeological objects. Distance from object and camera between 0.5m and 10 m.	Single elements and complete architectonic and archaeological features. Depends on laser range. From 2m to 1000m.
Resolution of measured points	In millimetres or centimetres depending on the size of the object photographed. The operator's zonal interpretation means that for zones with no relief plans are made. Point files can be manipulated by other programmes (100,000 points). A single study can contain several	In millimetres or centimetres depending on distance from scanner to object. This implies: - Millimetric precision for very close points. - Decimetric precision for distant points. Resolved by making several scans in bands.

	overlapping stereoscopic models. La interpretación por zonas del operador hace que para zonas sin relieve se realicen planos.	Very high precisión involves files with many millions of points that are impossible to manipulate.
Estimated time in the field for a 10m long model	Photographic acquisition 5 min. Station set-up and determination of points 15 min. Dismantling 3 min.	Scanner – laptop set-up 15 min. Scanning 15 min. Photographic acquisition 2 min. Dismantling 5 min.
Estimated time in studio for 10m model	Data import. Model orientation Correction Generation of texturized 3D model. Approx. 90 min.	Study import. Filtering of unwanted elements. Modelling and texture application. Approx. 20 min.
Total estimated time for 10m model	Approx. ………………… 2 hours.	Approx. …………….. 1 hour.
Estimated time in field for **100 m** model.	Photographic acquisition by pairs 15 min. Station set-up: dependent on conditions. The station must be moved to continue measuring points. 2 Station set-ups and control point determination 1 hour.	Dependent on conditions – scanner position must be changed. 2 scanner set-ups 25 min. Scanning 30 min Photographic acquisition 4 min. Dismantling 10 min.
Estimated time in studio for 100m model	Data import. Model orientation Correction Generation of texturized 3D model. Approx. 6 hours.	Study import. Model merging. Filtering of unwanted elements. Modelling and texture application. Approx. 1 hour.
Total estimated time for 100m model	Approx. ………………… 7 hours.	Approx. ………………. 2 hours.
Estimated time for larger models	Impossible to estimate. Dependent on visibility conditions. Possibly not feasible in some cases.	Dependent on model visibility from scanner position. Many hectares range with good position. The scanner shows its true potential in complex scenarios.
Manipulation by operators.	Easily exportable to other more conventional formats (DXF, WRML, etc.) and therefore available to other operators for data acquisition.	The models are so complex that special, very expensive software is required for their manipulation. Although they can be exported to other formats, the data cannot be manipulated. The necessary information (plans, elevations, cross-sections, etc.) are managed by the programme itself. The final product must be requested.
Problems and advantages.	P) The hidden zones in some photograms cannot be measured, making it necessary to produce more models or adjust the result by hand. A) The speed and ease of photogram acquisition produces elements clear of	P) As with photographs, hidden zones cannot be measured. Scanner position must be changed to capture them. P) The laser captures unwanted elements (people, cars, vegetation,

	unwanted objects, such as cars or people.	etc.), creating shadows on the model as well as floating points. A) Fascinating results, rapidly obtained.

4. Conclusions

Photogrammetry and laser scanning are both suitable techniques in heritage documentation as they allow us to obtain accurate metric data. However each of them has advantages and disadvantages as we have showed in the previous table. The Laser-scanner is very fast in fieldworks bat the main trouble is that the hardware is very heavy and it's inappropriate in very close range places. Nevertheless, the results show that photogrammetry and laser scanning both allow obtaining accurate metric data and, by means of it, we can document Historical Building and identifying structural pathologies, in shape and dimensions, which are very important in heritage policies [3].

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