Proceedings of the 38th Annual Conference on Computer Applications and Quantitative Methods in Archaeology, CAA2010
F. Contreras, M. Farjas and F.J. Melero (eds.)

3D Scanning. Low-cost Alternatives in Archaeology

Barrera, J.A.[1], Benavides, J. A.[2]
[1] Dpto. Ingeniería Gráfica, University of Seville, Spain.
[2] Dpto, Expresión Gráfica Arquitectónica y en la Ingeniería University of Granada, Spain
barrera@us.es, jbenavid@ugr.es

Despite the existence of several systems which achieve data acquisition of the 3D geometry of archaeological sites, most of these instruments remain overly expensive and too specialized for some professionals. These sophisticated instruments are often used to take a massive quantity of data, process and model to, ultimately, obtain only one simple section. Considering these circumstances, this paper shows a simple and low-cost system that has been developed, which fulfills the need for the definition of a specific geometry by using conventional CAD software.

Keywords: low-cost surveying laser scanning, 3D modelling.

1. Introduction

Documentation of heritage must show real geometry instead of an ideal or theoretic geometry as defined by the project or the original conception of the construction (ALMAGRO, 2004). The real geometry of historic buildings is the result of deformation, damage, and pathologies suffered by the constructions during their existence (PIERACCINI, 2001). Various technologies currently exist which enable a great amount of geometrical data to be available. In only recent years, has it been possible to quickly attain surface geometry, thanks to the new laser scanner (BARBER *et al.*, 2001). However, hardware and software capable of managing such enormous point clouds, such as those generated by a scanner, remain very expensive and often cannot automatically solve all the issues in relation to the graphic documentation required.

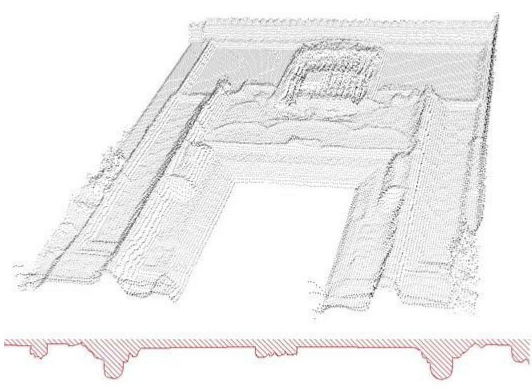

Figure 1: *Alcázar of Seville. Scanned point cloud to obtain a horizontal section. Author.*

Nevertheless, in practice, a large proportion of archaeological case studies can be carried out without any need for these dense point clouds and only require some sections that are determined through marked points in order to produce plans, elevations and sections.

In this paper a low-cost method to obtain plans, and sections by means of a combined technique of laser scanning and photogrammetry, is presented. The results of the application of this method are compared whith those obtained using a 3D scanner.

2. Modeling issues of complex and irregular shapes

Several algorithms can successfully solve 2D and 2.5D triangulation that are the long-established way to modeling surfaces. But real 3D triangulation is still an issue that presents serious problems, especially when automatic processes are required (BERALDIN, 2004).

An alternative to model 3D shapes consists on generating NURBS between consecutive parallel sections of the object to model (BARRERA, 2006). This is the foundation of the procedure used in these low-cost systems.

Numerous 3D programs allow modeling process to be carried out, and then our work focuses on an easy method to obtain object sections. Obviously, the ideal situation would be to have an dense enough point cloud captured by a 3D scanner or a photogrammetric system, when we can interpolate and obtain sections as closely as we want (BENAVIDES and BARRERA, 2008). But if it is not possible, we need to capture the shapes geometry and, in this case, we just need profiles at an adequate distance.

Figure 2: *Profile obtained by means a laser plane in a tract of almohade wall in Seville.*

Thus, the objective is to obtain orthogonal profiles without using an invasive method, quickly and that permits a restitution using a systematic method (HERRÁEZ *et al.*, 2005).

The solution is experienced in projecting a laser plane substantially perpendicular to the surface. To get the laser plane we can use several devices like the Leica Lino L2 (http://www.leica-geosystems.com).

This plane, by impacting on the surface, projects a line on the surface that can be photographed with a red filter, thereby generating the raster version of the section.

A key benefit of this procedure is that the profiles or lines are projected in locations that we are interested in for modeling. It can be projected vertically, horizontally or aligned with ornamental object or constructive features whose profile we are particulary interested in or as part of the larger digital model that will be obtained, that will reflect construction details, deformations or material losses, etc.

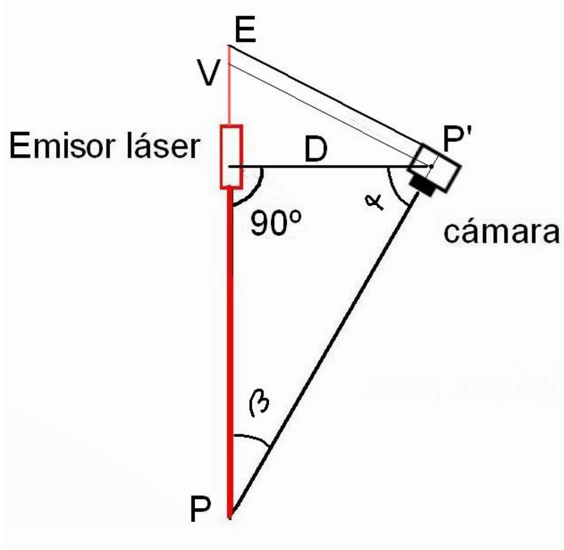

Figure 3: *Diagram showing the triangle-based capture-system performance. The distance D from the camera to the laser plane and the β angle formed by the plane and principal axis of the camera, are known. In this way, the homology parameter between the section and its image can be deduced.*

For the restitution of the sections, we have used two different procedures depending on the type of object we want to document:

2.1. Triangle-based restitution.

This system uses the same principle as laser scanners based on triangulation, which is also the most commonly used for dimensional control.

In accordance with the diagram above, if the P' point on the laser plane is folded open, taking the E line (intersection of the laser plane with the plane of the photographic image, negative or CCD) as a hinge, then 2D homology is obtained, where E is the axis, V is central point of the homology, and P and P' are homologous.

However, despite the versatility inherent in its use (since no additional composition of the setting is needed), with this procedure, the results exceed the tolerances fixed in our tests if the device is located at a distance greater than 5 meters. To improve the results, the distance between the laser emitter and the camera should be augmented, an inappropriate option for archaeological work, since the flexibility and versatility of use, which is one of the advantages of this system, would be lost.

2.2. Restitution by means of four homologic points.

This method allows the realization of the photo shots from any position, with or without a tripod. It consists in obtaining the relative coordinates of four points in the plane of the section, andby these, restore the image of the section through the homographic relation between points on a plane, and its image in the photograph.

We propose two different ways of obtaining the coordinates of all four points

1. Using a Total Station (EDM) or any other topographic measurement method.
2. Interposed in the laser plane four linear elements whose geometry is known.

In the latter case, the laser plane always stays parallel to a starting position, while changing location when necessary depending on the geometry of the object that must be registered. The laser will project a perpendicular plane to an existing item, or expressly provided one in the scenario, whose cross-section is known. This way, we will use the section known for homographic transformation that gives us the true extent of the section represented on the object. The key advantage is that it won't be necessary to use a Total Station, so that the entire collection can be done with very low-cost instruments.

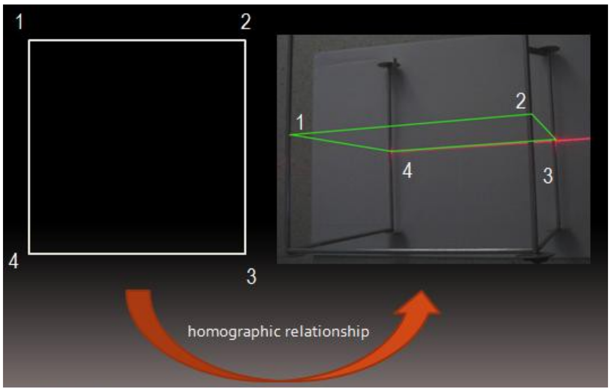

Figure 4: *Reference section from the 4 points determined by the laser.*

One of the advatages of this system is its flexibility when obtaining photos. The only necessary condition is to capture both the sections produced by the laser reflectedon the object, and the profile that serves as a reference.

3. Design and implementation of free software adapted to data capture and modeling process.

To obtain the true geometry of the section, a simple software application has been programmed that systematized the obtention of the true shape of the section knowing previously the geometry of the reference element.
The application has been programmed in VBA (visual basic for specific applications to AutoCad ®), that can be used in one of the most important graphical interfaces used in architecture. The algorithm is based on a process that performs projective homographic transformation of the obtained profiles over the sections of the virtual model.

The program has as inputs the parameters of the homographic transformation and the profiles to be restituted, the output provides the true-shape profiles Parameters and entities can be provided in text file mode or directly from the graphic editor.

The needed parameters are 4 couples of points, each one composed by a real point and its position in the image, and obviously, they must be coplanar and lineally independent in order to be able to define the homography. Logically, these points must be objectively pointed out on the projected image (for instance, the photograph).

Keep in mind that if the image is a photograph taken by a non metric camera, the optic distortion must be corrected. This means that the camera has to be previously calibrated.

The program can import the coordinates of reference points from a plain text file, which permits the obtention of these point through the use of a total station or any other measuring system.

Figure 5: *Section produced by the laser plane on the object and the reference profile.*

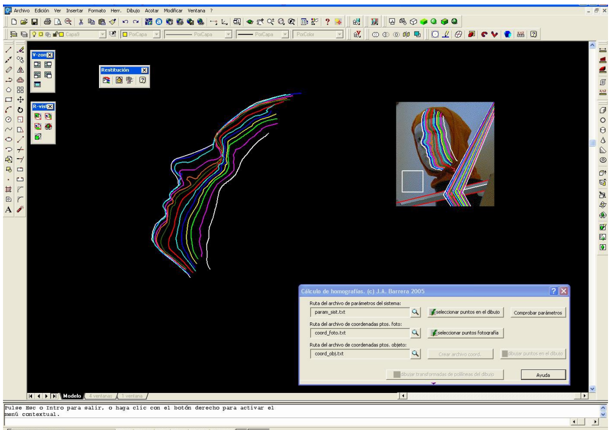

Figure 6: *A screen capture of a case study using the application RestiLaser.*

Obtained results and conclusions

Tests with midday daylight have been carried out to check the limitations of the system. Even at 11:30 am during the summer in Seville, the laser line can be distinguished in a picture taken with a camera with a red filter (same wavelength as the laser used, 633 nm). The laser that was used in this case study is an inexpensive commercial product that includes a leveling system very suitable for our work. Nevertheless, from distances of 10 or 15 meters it is necessary to use a professional laser, significantly being cheaper in recent years, and are widely used in the field of construction, like the Lino L2 mentioned above. There are also very powerful lasers for a wide variety of uses that overcome any difficulty in viewing and have truly affordable prices and whose employment in our proposal is in testing phase and will be subject to our future research.

Figure 7: *Red laser visibility using a red filter. September, 11:30 AM. Author.*

In comparison between the sections obtained by means of our method, and sections obtained from the point clouds captured with a Leica HDS 3000 laser scanner, it can be stated that there is no difference greater than 3 mm.

Our system also presents many possibilities of automation: we can synchronize the photos and the displacement of the laser via control of the cameras software. Back to the main issue, it could be implemented a function that automatically vectorizes sections and extracts its true shape, and then records them with different positions of the laser plane, thus gaining a wireframe model of the object in almost real time.

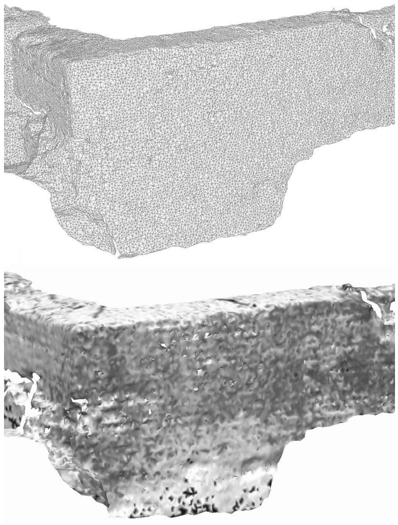

Figure 8: *Delaunay TIN of the points cloud and render of the output shape. Author.*

References

ALMAGRO, A. Levantamiento arquitectónico. Granada. *Universidad de Granada*. 2004.

BARBER, D.; MILLS, J.; BRYAN, P. Laser Scanning and Photogrammetry: 21st century metrology, *CIPA Symposium*, 2001. Postdam, Germany, 2001.

BARRERA, J.A., 2006. *Aplicación de tecnologías innovadoras en la documentación geométrica del patrimonio Arquitectónico y Arqueológico*. Tesis doctoral. Universidad de Sevilla. 2006.

BENAVIDES, J.A.; BARRERA, J.A. Advanced systems of measure for the graphical documentation of the patrimony. *CIPEG*, Granada 2008.

BERALDIN, J.-A. *Integration of Laser Scanning and Close-Range Photogrammetry* - The Last Decade and Beyond, XXth Congress. International Society for Photogrammetry and Remote Sensing. Commission VII, pág. 972-983. NRC 46567. Istanbul, Turkey, 2004.

HERRÁEZ, J; BARRERA, J.A.; HERNÁNDEZ, D. *La muralla almohade de Sevilla. Aplicación de tecnologías de vanguardia a los levantamientos en arqueología y restauración en Aparejadores*. Pág. 48 - 55. Sevilla, 2005.

PIERACCINI, M. ; GUIDI, G.; ATZENI, C. 3D digitizing of cultural heritage. *Journal of Cultural Heritage*, Volume 2, Issue 1. Pág. 63-70, January-March 2001.