Virtual Archaeology Review

Integration of photogrammetric and terrestrial laser scanning techniques for heritage documentation

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Resumen

Este trabajo presenta las ideas y trabajos preliminares del proyecto Integración de Técnicas de Fotogrametría y Escáner Láser Terrestre para la Documentación Patrimonial (IFOTEL TIN2009-09939; Ministerio de Ciencia e Innovación, Plan Nacional I+D+i, 2008-2011), con el que se pretende buscar la mejora y optimización de la documentación del patrimonio cultural mediante la combinación de diferentes métodos, especialmente de fotogrametría (tanto terrestre como aérea mediante el uso de plataformas ligeras), técnicas de barrido láser (LÍDAR terrestre) y topografía, que aúnen las ventajas de todos ellos minimizando sus inconvenientes.

Palabras Clave: *DOCUMENTACIÓN, FOTOGRAMETRÍA, LÍDAR TERRESTRE (TLS), CÁMARAS NO MÉTRICAS.*

Abstract

This paper presents the preliminary works of the Integration of Photogrammetric and Terrestrial Laser Scanner Techniques for Heritage Documentation Research Project (IFOTEL TIN2009-09939; Ministry of Science and Innovation, National Programme R+D+I, 2008-2011). The IFOTEL project aims with the improvement and optimization of heritage documentation by means of combination and integration of different methods and techniques, mainly close range photogrammetry (both terrestrial and aerial with light platforms), terrestrial laser scanner and surveying, joining the advantages of the different methods but also minimizing the disadvantages of each single technique.

Key words: *DOCUMENTATION, PHOTOGRAMMETRY, TERRESTRIAL LASER SCANNER (TLS), NON METRIC CAMERAS*

1. INTRODUCTION

Cultural heritage is a record of the human past and, as such, heritage objects show a large variety in their nature, size and complexity. This cultural heritage is affected by a continuous damage and erosion as time goes by, past and present wars, natural disasters and the own human negligence. The importance of proper cultural heritage documentation is well recognized at international contexts. Thus, the International Committee for Documentation of Cultural Heritage (CIPA-Heritage Documentation; CIPA, 2010) states that: *"a monument can be restored and protected only when it has been fully measured and documented and when its development has been documented again and again, i.e. monitored, also with respect to its environment, and stored in proper heritage information and management systems"*. Dealing with these purposes, this paper presents the preliminary works of the *Integration of Photogrammetric and Terrestrial Laser Scanner Techniques for Heritage Documentation* Research Project (IFOTEL). This project aims with the improvement and optimization of heritage documentation by means of combination and integration of different methods and techniques, mainly close range photogrammetry, terrestrial laser scanner and surveying.

2. MEASURING TECHNIQUES FOR HERITAGE DOCUMENTATION

At present, cultural heritage documentation projects use a variety of spatial data acquisition techniques such as conventional surveying, photogrammetry and terrestrial laser scanning (TLS). The selection of the proper technique, the appropriate procedures (both data acquisition and reduction methods), the optimum workflow design, the metric quality of the final products according with the required technical specifications, is always a challenging matter. Choosing the proper method can be a difficult task. There are authors that advice about the use of photogrammetry as an image-base method which provide valuable semantic information. Advantages of image-base methods are related to their level of details, economic aspects, sensor portability, handling in spatial limited environment and a short data collection time. Disadvantages remain in the post processing when the texture of the object is poor and the shape is complicated (PATIAS et al, 2008).

With respect to sensors, since extensive use of non metric cameras is being employed in IFOTEL (PEREZ_GARCIA et al, this congress). So techniques for lens calibration must be applied. Field and plumb line calibration methods are appropriate techniques, being the lens distortion the main error source in these kinds of cameras. Because instability of zoom lenses, fixed focal length lens with SLR cameras are preferred to those zoom lenses compact cameras.

Besides, there is no doubt about the high performance of the laser techniques. The advantages of TLS are related with the high capacity in the spatial data acquisition in short time periods. TLS captures both spatial point data and radiometric information (RGB and intensity). The huge data capture (point clouds can be hundred thousand or million of data acquired in few hours) allows the generation of great detailed and reliable surface models. But some drawbacks come from this capability and the huge dataset are great problem in post-processing. Also, TLS technique is not optimum for linear elements capture and, in general, the high density data acquisition requires a further filtering and data removal.

Because the complex structures of objects and sites in cultural heritage, those typical geometric assumptions made in architecture and/or archaeology (such as verticality, parallelism, perpendicularity, vanishing points or symmetry) cannot be applicable. Thus, the recording of such sites results in a huge amount of data and therefore the need for automation arises. Whereas photogrammetry implies a cumbersome manual and very time consuming data edition, even in case of automated or semi-automated digital techniques, neither the automation in TLS heritage applications is fully developed (PATIAS et al, op.cit.). Therefore, in many cases it is not the matter choosing the proper unique method, it is better to integrate several techniques joining the advantages of all of them, but also minimizing the disadvantages of each single technique.

Also the combination of both terrestrial and aerial techniques means an interesting option in many heritage documentation projects. The chance of rise sensors and capture the information (rather difficult to obtain at ground level, for example at archaeological sites) increases the performance of the methods. So we can use aerial platforms controlled from the ground. They are the unmanned aerial vehicles (UAV). These UAV's can be model airplane or helicopters radio-controlled, helium balloons and blimps, or even kites (EVARAERTS, 2008).

3. IFOTEL PROJECT

The IFOTEL project is being applied to different circumstances with respect to object nature, complexity, extent and working scale in the province of Jaén (Southern Spain). We can mention examples of Neolithic rock art (petroglyphs and pictograms) in rock shelters, objects and artifacts, mason's marks, bas-relieves, surveys at archaeological sites (for documentation and monitoring of the excavation progress) and historic buildings and monumental sites in deterioration progress, such as castles and fortress.

At very large scale there are lots of examples about artifacts found in archaeological excavations such as two bone figurines representing both male and female anthropomorphic idols (Chalcolithic Age from *Marroquíes Bajos* Site in the city of Jaén; IIIrd millennium BC). These figurines (approximately 12 cm length) have been surveyed by means of digital photogrammetry and close range laser scanner (Minolta 700 Vi). Because the nature of these artifacts, probably 3D modeling is the more appropriate output for geometrical analysis (MOZAS et al, this congress). Figures 1 and 2 show different views of the 3D model (generated by laser scanner) as well as actual images taken with a digital camera.

Figure 1. Different views of a 3D model of the female anthropomorphic idol (Marroquíes Bajos Site, Chalcolithic age, III millennium B.C.

Figure 2. Photogrammetric analysis of the female figurine with a non metric digital Canon D30. Front and rear views of stereo pairs and anaglyphic images.

In the vicinity of Jaén there are also examples about petroglyphs in open-air rock shelters (Figure 3). Because accessibility and visibility problems, light equipments are recommended such as digital non metric cameras (both reflex and compact cameras). TLS and total stations cannot be used so the object control is mainly reduced to tape measurements. Digital surface models can be acquired with modern digital photogrammetric techniques from conventional mapping digital photogrammetric workstations -DPW- (i.e. Socet Set® or Leica Photogrammetry Suite -LPS®-, etc.) or a desktop DPW (i.e. Photomodeler®, ShapeCapture®, etc.). A previously calibrated compact zoom camera (12 Mp Canon G10) was used. Output products are digital surface models of the engravings and some image products (such as orthophotos).

In these examples, urgent documentation is needed since the site preservation is not guaranteed. Although Neolithic rocks engravings located in Jaén province are protected by law, the rock shelter shown in figures 3 and 4 is being used as cattle pen.

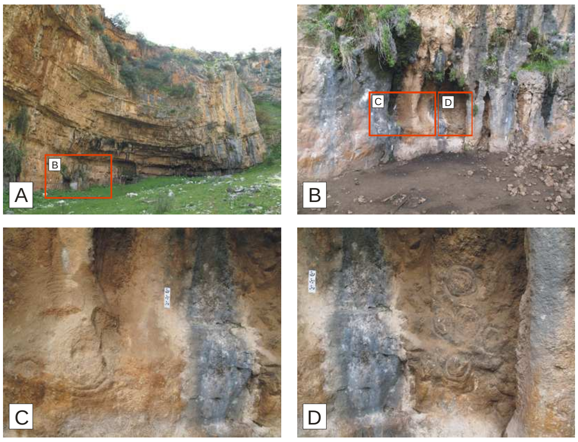

Figure 3. Example of open-air shelter in Jaén province with Neolithic rock engravings.

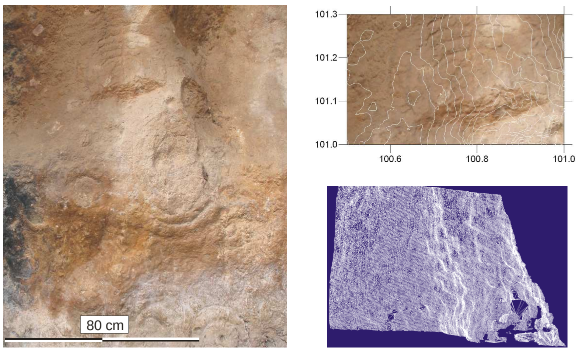

Figure 4. Details of petroglyphs of figure 3C. Orthophoto (left) of 2 mm pixel size (ortho projection was done onto a mean shelter surface);ortho with contour levels (1 cm interval; upper right); and triangulated mesh of the engraving (lower right).

Also detailed digital surface model can be produced by photogrammetric techniques in case of bas-reliefs. Although close range TLS can produce high reliable surface models, sometime TLS cannot be used because improper ambient light conditions, accessibility to the area of interest, availability of close range equipments or economical constraints. Figure 5 shows the photogrammetric analysis of mason's marks with a non metric compact zoom camera (12 Mp Canon G10).

Anyway, combination of both TLS scanner and photogrammetry can improve and optimize the heritage documentation process similar to recent developments in mapping technology. Imaging and laser systems can be complementary and disadvantages of one system can be compensated for by advantages of the other system (HABIB, 2009). TLS allows a high reliable spatial information and photogrammetry gives a valuable semantic information for interpretation, data edition, combination of multispectral images (if appropriate sensors are used) and image-based output products such as orthophotos.

Figure 6 shows an example of TLS survey (Optech Ilris 3D) of the Convento Church (XVIIIth century; Montefrío, Granada) combined with a photogrammetric survey carried out with a reflex digital camera (full frame -36 x 24 mm- 12 Mp. Canon D5) and fixed 35 mm focal length. Detailed laser surface model can largely improve the orthophoto generation. But in terrestrial and complex examples such as those found in architectural and archaeological surveys, differential rectification (the standard procedure for orthophoto generation) can lead to important problems (double or ghost images, hidden areas, image stretch, etc.). To avoid these problems true orthophoto rectification should be used.

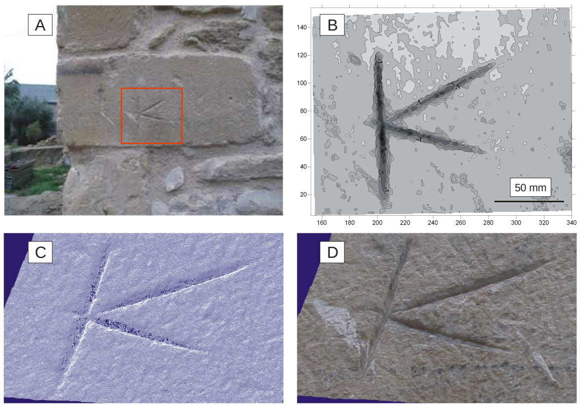

Figure 5. Analysis of mason's marks in Lopera Castle (XIII th century; Jaén province). A: mason's mark; B: digital surface model with contour levels (1 mm contour interval) obtained by photogrammetric correlation; C: triangulated mesh; D: photorealistic model.

Figure 6D also shows these orthophoto problems in complex objetcs. Additional elevated photographs are needed in order to select appropriate textures for occluded areas. Tall mast, helium balloons or radio controled helicopters with orientable camera platforms (to allow near horizontal or oblique photographs) can help to overcome this kind of problems.

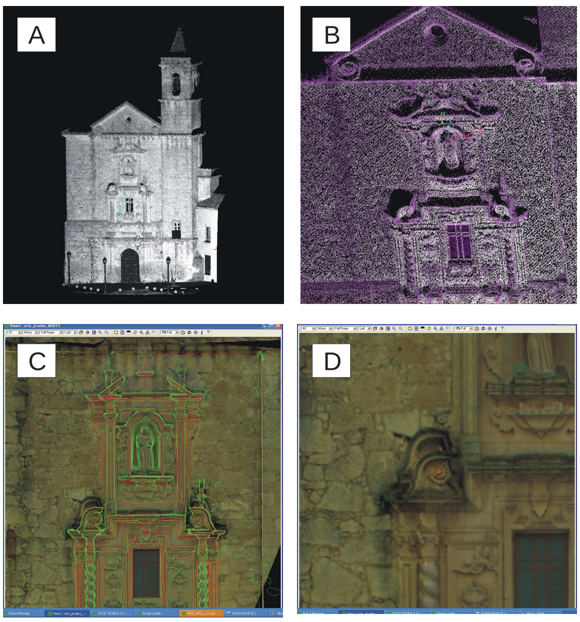

Figure 6. A and B: Convento Church (Montefrío, Granada) captured

with a TLS Optech Ilris 3D; C: Details of DSM (green lines) along with break lines (red lines) with the orthophoto of the façade; D:Ghost images above the column (correctly orthorectified) are visible

A last example is a photogrammetric survey of an archaeological excavation in an Iberian settlement at *Cerrillo Blanco* Site (a necropolis of VII-VIth B.C. in Porcuna, Jaén province). An outstanding sculptural group was found in this site in 1975, which it is now exhibited in the Museum of Jaén. At present new archaeological prospecting is being carried out, so a photogrammetric survey was done for the basic mapping of the site. The approach has been aerial photogrammetry from a tethered helium balloon (2 m diameter) and a reflex camera suspended from a *Picavet* mount (to avoid oscillations) with a radio controlled camera mount (figure 7). A *flight* was planned with 5 overlapping strips and more than 80 photographs were processed in order to generate a detailed digital terrain model, an orthophoto map (with 1 cm GSD) and a 3D model of the site (figure 8). After concluding the new excavations, a new photogrammetric survey will be performed in order to update the cartography and evaluate terrain changes.

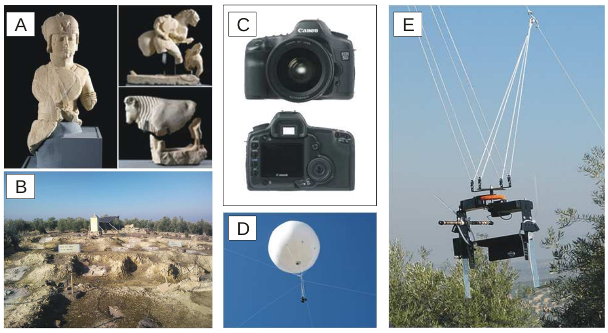

Figure 7. Cerrillo Blanco Site *(VII-VIth B.C., Porcuna, Jaén). A: Iberian sculptural group (http://www.juntadeandalucia.es/cultura/museos/MJA/); B: Panoramic of the site; C: SLR Canon D5 used; D: helium balloon; E: Picavet and RC camera platform suspended from the tether line.*

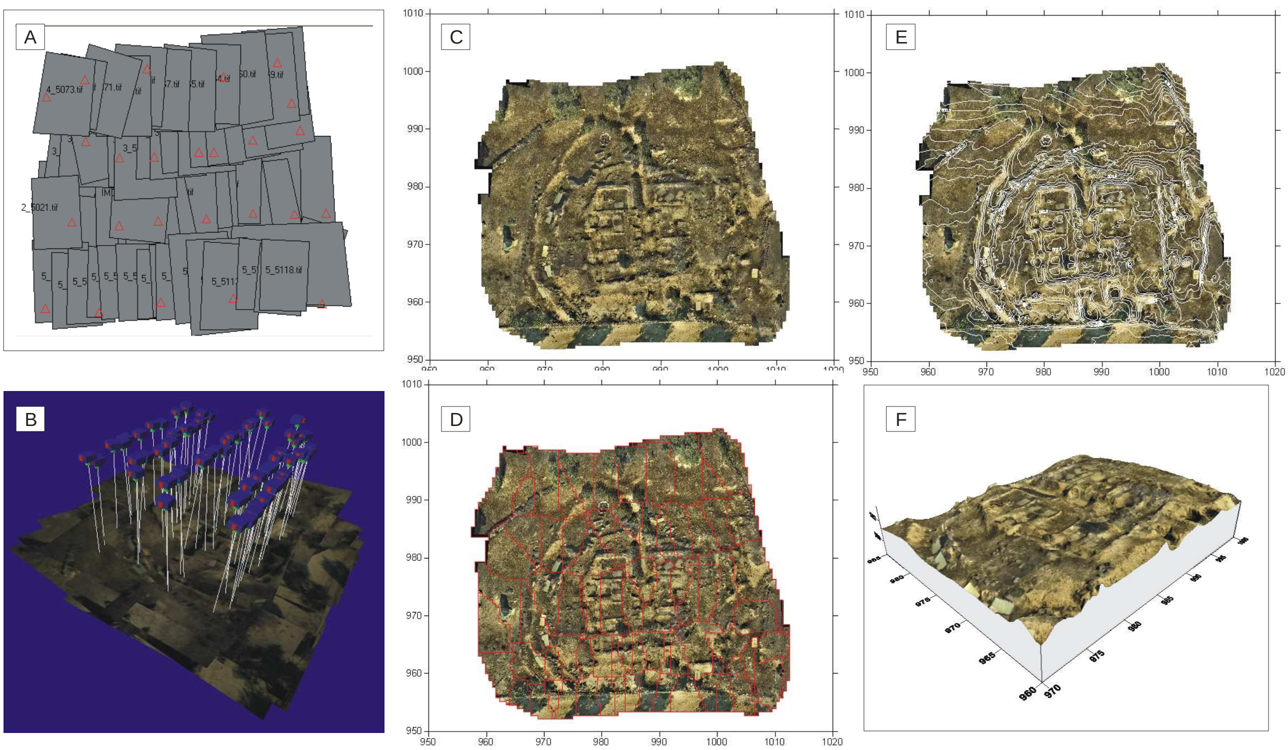

Figure 8. Photogrammetric survey at Cerrillo Blanco Site. A and B: Footprint images and 3D view of the 5 strips photogrammetric block; C: Orthophoto 1 cm GSD covering an area of 50 x 50 m; D: Orthophoto mosaic; E: orthophoto map (20 cm contour interval); F: Virtual 3D model of the site.

4. CONCLUSIONS AND FUTURE WORK

The presented project set out two methodological levels. First, IFOTEL will develop and improve the methods and algorithms to make more effective the documentation with respect to the different single techniques: optimization of calibration methods for non metric digital cameras; improvement of georeferencing camera poses and scan stations; processing, orientation and clasiffication of scanner laser point clouds; true-ortho generation; etc. And second, the methodological appoach implies the integration and combination of different documentation techniques for improving and optimizing the whole process. Such techniques will be: close range photogrammetry, laser scanning (close and long range scanner), multi-spectral sensors, light unmanned aerial platforms –kites, helium balloons and tall masts-, GPS and gyroscopes for sensor pose and attitude and robotized total stations.

Finally, some simple and low cost methods are also being developed in order to be applied by heritage experts not skilled in measurement techniques (mainly archaeologists and architects).

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