DIGITAL PHOTOGRAMMETRY AND LASER SCANNING IN SURVEYING THE “NYMPHAEA” IN POMPEII

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ABSTRACT:

A study currently carried out with archaeologists from Bologna University involves the restitution of the nymphaea existing in Pompeii (Naples, Italy); this task requires a long work using classical photogrammetric techniques. Different solutions were tested using digital photogrammetric systems, in terms of data acquisition (e.g. semi-metric vs digital cameras, Cyclop system), data processing (e.g. automated surface model reconstruction, monoscopic or stereoscopic plotting) and representation (e.g. orthophotos, adoption of cartographic projections), but this kind of object could be an interesting application also for laser scanning techniques. The decoration of nymphaea apsidal and front walls is particular rich in some cases, and deformation of surfaces are sometimes well evident, so the integration of the opportunities provided by close range digital photogrammetry and laser scanning could be a topic of interest. A multi-station laser scanner survey could permit to complete the planned activity in shorter time and with an adequate accuracy, with the production of a complete 3D model; this solution has been tested through the comparison with digital photogrammetric survey in terms of precision and reliability in restitution of the object size and shape, with the final aim to understand what kind of solution better supports the study and the accurate metrical documentation of the nymphaea. The paper presents the test currently carried out on two nymphaea.

1. INTRODUCTION

The research here described regards a project started in 1999, within a collaboration established between the University of Bologna and the Archaeological Superintendence of Pompeii. The project pointed out originally the study, restoration and valorisation of the Centenary Insula (IX.9), regarding an interesting house known as “of the Centenary” that would be scientifically recuperated and made available (Scagliarini Corlaita and Coralini, 2002).

In the frame of this project was successively activated a rigorous survey by digital photogrammetry of the most significant nymphaea of Pompeii. The nymphaea are elements of remarkable archaeological and also artistic value. Important houses of Pompeii were decorated with nymphaea. Like other structural elements they showed the social and economical status of house proprietary, so the pictures on walls and apsidal and the material used were sometimes particularly fine, giving artistic value to the objects. In Pompeii area about 15 examples of nymphaea are known, characterised by different geometry and structure. During 1999 and 2001 campaigns the surveys of six nymphaea were carried out, located in Centenary house, Grand Duke house, Small And Big Fountain houses, Wounded Bear’s house, Scientist’s house.

The nymphaea have been chosen with the aim to furnish almost an example of every architectural and decorative typology, so a preliminary phase was planned to study surveying and representation methodology appropriate for each specific typology based on the geometrical characteristics of nymphaea. The research in those phase regarded the survey and restitution through the utilisation of digital photogrammetric methods, evaluating alternative techniques by means of direct photogrammetric comparisons (Bitelli et al., 2001). The research is not concluded and in 2002 campaign further processing and data acquisition for other nymphaea is planned. The photogrammetric restitution produced 3D object model and raster products. An high degree of detail was maintained in the image acquisition and plotting process, trying to preserve the richness of nymphaea apsidal and walls decoration in the graphical representation. Even the deformation of nymphaea surfaces are in some cases well evident.

In order to verify the reliability of different techniques of investigation with respect of richness and detail object description and eventual deformation detection, the integration of different close range digital photogrammetry techniques and laser scanning was planned. The latter is certainly an emerging technique for industrial and architectural applications, as well as in the field of cultural heritage and virtual reality based museums (Beraldi et al., 1999; Böhler et al., 2001; Monti et al., 2001).

A multi-station laser scanner survey could permit to complete the planned activity in shorter time and with an adequate accuracy, with the production of a complete 3D model. The solution has been tested through the comparison with digital photogrammetric survey in terms of precision and reliability in restitution of the object size and shape.

The different techniques were pointed out to understand which solution could better supports the study and the accurate metrical documentation of the nymphaea in respect to geometrical and artistic typology.

The current work will be briefly described in the next paragraphs, taking as example the survey of the nymphaea of the “House of the Big Fountain” and of the “House of the Small Fountain” (fig.1).
Fig. 1 – Sketch with the position of the nymphaeum in the adjacents "House of the Small Fountain" (top) and "House of the Big Fountain" (bottom).

2. TECHNIQUES APPLIED

2.1 Photogrammetry

The subject of the surveys (the nymphaeum in Pompeii) is generally of a relative small size, with different kind of geometric characteristics, from a very simple structure to quite complex surfaces. For the photogrammetric image acquisition, and mainly due to handiness requirements, the choice has been for small and medium format semimetric cameras, but also a calibrated digital camera was adopted. In particular were used Leica R5 (24x36 mm) and Fuji 690II (60x90 mm) film based cameras with reseau (equipped with wide angle and normal lenses) and Nikon D1 digital camera equipped with a wide angle lens. Normal and convergent photos were acquired, in order to apply classical stereoscopic plotting but also in some cases monoscopic non conventional techniques. A solution for a good stereoscopic coverage is represented by the use of the Cyclop system (Menci and Rinaudo, 2000). It is a single camera system (fig.2) that, simulating the use of a bi-camera, provides a specific software for mono- and stereo-restitution without requiring a topographic survey for ground control points determination.

Fig. 2 – House of the Small Fountain: digital data acquisition using the Cyclop system.

To provide a solution for the exterior orientation problem, three different approaches are applied:

- a conventional topographical survey of the GCPs, using special retro-reflective targets and high precision total stations (with normal EDM or reflectorless system): this solution provides the best results in terms of accuracy, with error ellipses of few millimetres, for the point determination and for the absolute orientation;
- the scaling of the 3D model, derived from a relative orientation, by using distance measurements between well defined points;
- the employing of the Cyclop system as a bi-camera, with a base value of 1.20, 0.90, 0.60 or 0.30 m depending on the size of the object (therefore adequate to the case in question).

The orientation procedures (inner and exterior) are performed using a PC-based digital photogrammetric workstation (StereoView, Nikon Instruments) and also by an analytical stereoplotter (Digicap40, Siscam). Different products were until now produced and their use considered with archaeologists:

- classical large scale three-dimensional vector restitution, either by analytical and digital stereoplotters;
- monoscopic restitution of the main structure using digital photogrammetric programs, aided by automatic correlation and epipolar constraints for homologous point collimation;
- design of profiles and sections;
- digital surface model determination, either by manual operation and by automatic matching procedures;
- digital rectified photos and orthophotos.

Some examples are shown below, relative to surface modelling and derived orthophotos. Orthophotos, despite the difficulty of their application in architecture, provide a very powerful tool for restoration and documentation of monuments and materials; for their generation the capabilities of image matching procedures could be successfully exploited but they require appropriate a-posteriori manual editing (Baratin et al., 2000).

Figure 3 shows the results of a comparison between manual and automatic (without editing) DSM generation, at a 10 cm grid spacing, for the Small Fountain nymphaeum; the surface was...
generated by the StereoView digital photogrammetric package. The same program, but in this case with some manual editing of the original 5 mm grid, was adopted for the surface modelling of the masks from the Big Fountain nymphaea; the results for the left mask is shown in figure 4. The automatic 2 cm grid DSM, after some a-posteriori manual correction, has been the base for the orthophoto of the facades; a particular for the upper part of the Small Fountain front is represented in figure 5. Finally, figure 6 shows, using a simplified 3D reconstruction, the results of mosaic composition for the digital rectifications (software Rollei MSR rel. 4) of the walls located nearby the Small Fountain nymphaea.

Fig. 4 - Particular from the House of the Big Fountain: the mask on the left part of the nymphaum. (a) Raster image depicted on the DSM obtained by automatic correlation, with grid and breaklines; (b) final orthophoto.

Fig. 5 - House of the Small Fountain: 1:25 digital orthophoto for the upper part of the front (reduced).

Fig. 6 - Mosaic of rectified images for the walls nearby the Small Fountain nymphaum in a simplified 3D reconstruction.

2.2 Laser scanning

For the two above mentioned nymphaea a laser scanning survey was realized by using the Riegli LMS-Z210 system (fig. 7). This system can perform data acquisition for objects at a distance from 2 up to 350 metres, with a nominal accuracy in the distance of about 2-2.5 centimetres. Different systems could guarantee a better accuracy on short distances and could provide perhaps better results for an object of this dimension. In archaeological or architectural situations involving a large range of working distances this product could however allow a wider assortment of applications.

Fig. 7 - Big Fountain nymphaum: laser scanning for a lateral station.

The system is able to acquire intensity, range and also RGB images for a scanning range of 370 gon (horizontal) x 88 gon (vertical), with a minimum angle step resolution of 80 mgon, either in horizontal and in vertical. The definition of a Cartesian world reference system for the point coordinates, otherwise expressed in the polar system, can be performed in different ways:

- using the standard instrumental orientation;
- by a coordinate system described by a specific plane and one axis or, in alternative, the origin and the normal vector of a second plane (method useful for the registration of a single scan);
- by a manual modification (move/rotate) of the actual coordinate system;
- via reference points (method useful for registration of multiple scans);
- by automated techniques relying mainly on the recognition of the same flat areas on contiguous scans.

Three scans were realised for the Big Fountain with 80 mgon resolution, one central (4 frames averaged) and two laterals, and only a central scan acquisition for the Small Fountain.

In order to better compare the results of the photogrammetric and lasercanning process, the same targets, whose coordinates were determined by a topographical survey, were used for the exterior orientation in both the two approaches.

Figure 8 shows the phase of automatic localisation of the targets, based on their high intensity values, realized by 3D RiVIEW Riegl software for the nymphaeum of the "House of the Big Fountain"; the coordinates of the targets were supplied as a separate file. The automatic localisation, and the subsequent use for stitching together different scans, was successfully tested using the program Laser Scanner Registration 1.0 (Borraz et al., 2002); the results, after a decimation of the cloud points, are shown in figure 9.

Fig. 8 - House of the Small Fountain: registering the scans by automatic identification and association of control points.

Fig. 9 - House of the Big Fountain, after automatic registration of three scans and subsequent point decimation.

The free visualisation software provided by the Riegl firm (or other programs) permits this combined cloud of points to be exported in .wrl format and easily explored by a VRML browser (fig. 10), and distances interactively and immediately measured between couples of points.

The successive step is the creation of the 3D mesh and the final 3D model, after a series of refinements that, as well known, in general require powerful software and hardware platforms.

Fig. 10 - House of the Big Fountain, interactive exploration of the three co-registered point clouds by a VRML plug-in in a standard browser.

3. COMPARISON AND INTEGRATION OF THE TWO TECHNIQUES

During these experimentations, some preliminary tests were realized in order to verify the accuracy gained by different techniques. Considering for instance about 40 differences in distance between couples of control points in respect to the values derived from the topographical survey we have:

Table 1 – Accuracy test: differences for absolute distances in respect to values obtained by total station surveying (values in meters).

<table>
<thead>
<tr>
<th>Method</th>
<th>mean</th>
<th>min</th>
<th>max</th>
<th>std.dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photogrammetry (ROR+AOR)</td>
<td>0.002</td>
<td>-0.012</td>
<td>0.012</td>
<td>0.008</td>
</tr>
<tr>
<td>Photogrammetry (scaled model coordinates)</td>
<td>-0.002</td>
<td>-0.021</td>
<td>0.011</td>
<td>0.010</td>
</tr>
<tr>
<td>Lasercanning (instrumental coord. system)</td>
<td>0.004</td>
<td>-0.020</td>
<td>0.022</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Taking in account the above mentioned limitations of this model of lasercanning for short distances and other experiences in literature, it appears that the accuracy provided by lasercanning systems is today well comparable with photogrammetry, and for some systems is better.

Some general considerations deriving from our experience can be briefly expressed.

The advantages of lasercanning, some of these in common also with photogrammetry, with respect to traditional surveying methods for archaeological sites and structures, and in general for cultural heritage preservation and documentation, could be briefly summarized as:
- short data acquisition time;
- very accurate 3D models obtainable from high density point clouds;
- non contact active sensing (no interference with excavation activities and no need to signalise the object);
- immediate results and easy measurements on the model.

Laser scanning peculiar characteristics are also the practicability of object replication (mould), and the support for virtual exploration and study via Internet, with a different approach in respect to photogrammetry and visual photographic reality (Bitelli et al., 2001).

In applications like those shown, laser scan could be a good solution to detect and model ‘out of vertical’ walls, providing a valuable support for structural monitoring and intervention.

On the other hand, archaeologists sometimes require from the survey a traditional product, in the form of a vector drawing with the main features well individuated, i.e. subordinate to a preliminary subjective filtering; the derivation of such a result from the laser model requires very powerful software and high skills where complex and not elementary geometrical shapes are involved, as is the case for numerous archaeological applications.

The choice of appropriate software is a crucial point for data processing, where strategies for data decimation and filtering, merging of cloud datasets and meshes, TIN tessellation, and finally generation of a polygonal model can produce quite different results (Fangi et al., 2001).

Photographic richness provided by photogrammetric image products is surely of high importance for archaeologists and architects, and true-colour imagery generated as a product of a laser scan, when available, is sometimes inadequate in quality and radiometric characteristics.

The integration of the two techniques, on the other hand, could provide very interesting results, starting from simple combinations: for instance, a stereoscopic model could permit the editing and integration of a incomplete laser acquisition (fig. 12), or the laser data could supply the coordinates for exterior orientation of photogrammetric images.

As depicted by other experiences, the use of laser derived DSM as a support for digital orthophoto generation do not directly provides satisfying results (see for instance figure 13 compared with figure 5), depending also on the object shape, data density, etc.; it requires at least an appropriate editing of the 3D model.

Furthermore, complex shapes require multiple scans and an accurate survey planning.

In this context, photogrammetry could play a relevant role to complement laser surveys, in order to detect or correct erroneous or missing parts of the datasets and to describe discontinuities by means of breaklines and points.

3D texture mapping of the clouds of points can be performed by using calibrated instruments and cameras (Kern, 2001), and the combination of laser scanning and photogrammetric systems could produce a complete object modelling, with highly accurate geometric and colour characteristics.

In the next future the integration of these techniques will play therefore a fundamental role in surveying for cultural heritage recording.

Fig. 13 - House of the Small Fountain: particular of orthophoto obtained by using surface model provided by laser scanning.

4. REFERENCES


5. ACKNOWLEDGEMENTS

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1. INTRODUCTION

The use of terrestrial laser scanning has been widely adopted in recent years as an innovative technique for the documentation and analysis of archaeological sites. This technology offers high accuracy and a large field of view, allowing for detailed and comprehensive surveys. The data obtained can be used for various purposes, such as 3D modeling, digital reconstruction, and digital preservation.

In this work, the authors describe their experience in using terrestrial laser scanning for the documentation of the Pompeii site. They highlight the advantages of this technology and discuss the challenges and limitations encountered during the project. The results are presented in a series of visualizations and data sets that demonstrate the potential of laser scanning for archaeological research.

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