INTEGRATION OF GEOMATIC TECHNIQUES FOR QUICK AND RIGOROUS SURVEYING OF CULTURAL HERITAGE

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ABSTRACT

The field of Cultural Heritage surveying is probably the most emblematic of potentialities offered by Geomatic technologies integration, either because of specific peculiarities presented by every case of study, and because frequently the work conditions impose a short acquisition time, a requirement that a multi-disciplinary surveying approach can today partially address and resolve. This is especially the case after a calamitous event, when a rapid and rigorous evaluation of object conditions and material decay can become fundamental.
The paper presents an experimentation carried out at the Mesopotam monastery (XIII century A. D.), in the framework of the Archaeological Mission of the University of Bologna at the Phoinike site (Albania).
The surveying operations involved different methodologies simultaneously applied: a long static GPS observation was conducted on a reference point established in the area, to perform the absolute geo-referencing of the site in ITRF2000, and the same point was used as master station for kinematic GPS survey, in order to realize an expeditious survey of the wall structures; in this way was also georeferenced a photogrammetric survey to support digital orthophoto and rectification production for a quick metric representation of monastery external facades, and a single-camera system emulating a stereocamera permitted the accurate stereoscopic acquisition of architectonical details without control points; the indoor interactive exploration by Quick Time Virtual Reality system proved a simple method to document the crack phenomenons state.
This survey represents an example of optimization and integration of different geomatic techniques and technologies to acquire in a short time by a small group a rigorous geo-referenced documentation of archaeological or architectural sites, with data related to the object and to its context.

1. INTRODUCTION

Accurate surveying is a key factor for Cultural Heritage preservation and valorization; it can be realized by routine activities or by special intervention in presence of specific situations. After a calamitous event like an earthquake, for example, the investigations that must be immediately activated are numerous and meet the requirement of managing the emergency and acquiring the mayority of information about the event and its effect in the shortest time (Bitelli et al., 2003a). Structures of architectural or archaeological interest, if not yet documented by metric products, or if severely damaged, need to be surveyed in a short time and with a reduced intervention by the operators. The survey must be in any case capable to produce an accurate geometric and qualitative description of the current situation of the structure.
The survey activities are complex and highlight the necessity of having at disposal a methodology that permits to intervene with tools, today offered by modern Geomatic technologies, presenting at the same time a fast application, an operative simplicity, limited costs, transferability of results and geometric accuracy.
The present work shows a possible integration of techniques for the collection of information about damage related to historical buildings. This multi-disciplinary approach, making use of fast and medium-low cost techniques, allows to collect in a very short time a large amount of information without the need of existing previous documentation. The experimented techniques range from static and kinematic GPS surveys to perform the absolute geo-referencing of the area and the description of the structures, to classical topographical surveys, to different photogrammetric methods for the restitution of the historic buildings, and finally the acquisition of photographic documentation by using the QuickTime Virtual Reality technique.

Figure 1 shows a scheme of the possible integration between the used surveying techniques to perform the complete metric site documentation.
The area interested by the experimentation is in Albania.

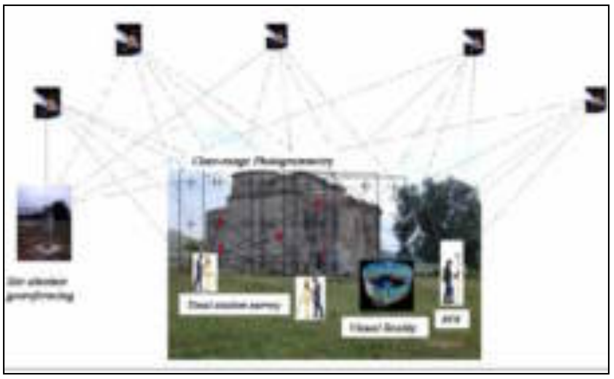


Figure 1. Absolute site georeferencing performed by GPS and its integration with other geomatic techniques.

The Archaeological Mission of the University of Bologna in Albania started in 2000 at the ancient town of Phoinike (De Maria et al., 2001; Bitelli & Vittuari, 2002); this area is placed in Epirus, in the ancient region of Caonia, in the south of current Albania, in front of Corfù island (Figure 2). Aim of the mission is also the study of the surrounding territory, containing many valuable, but still unknown, architecture and archaeology treasures
In the level area on the east side of Phoinike town, is the Mesopotam knoll, placed along an important connection way between hinterland and coast. An interesting monastery is there present, but the information about it is very limited; no documentation was in any case available to the authors at the moment of the survey, in 2001.

Figure 2. Geographic location of the site.

The site is an orthodox monastic complex, builded in the XIII century A.D. (Meksi, 1972), that presents a peculiar architecture characterized by the combination of different styles, in according with the dominations that have interested this area. For this structures, presenting evident decay state and some static problems (Figure 3), didn't exist any kind of metric description, absolutely necessary for an evaluation of the conditions; besides a geometrically accurate survey is an invaluable support for an eventual repair activity.
The survey was then performed with the double purpose of generating a rigorous survey of the structure and, at the same time, experimenting a solution for an effective integration of different modern techniques in the case of a disaster, where a quick survey of a structure become necessary.

Figure 3. Particular of the monastery interior
with a notable fissure in evidence.

In case of a calamitous event, the primary aim of survey activities is the collection of a large amount of data in the shortest time, in order to describe the damaging before the cleaning and reconstruction phases have to be started, otherwise the data get lost and cannot be retrieved; the effective data elaboration can be postponed, also in according with the requested final products.

2. THE SURVEYING ACTIVITY

The survey of the complex was realized in June 2001; the complete survey required half day only. The first problem addressed was the absolute georeferencing of the site, performed by GPS.

2.1 GPS Measurements

Long time GPS observations, spanning the overall period spent on the area, were firstly conducted using dual frequency Trimble geodetic receivers on a reference point established near the monastery; this permitted the connection of this point, denominated MES_0, to the IGS permanent stations of Perugia, Matera, Noto, Lampedusa, Dubrovnik, Sofia, Ohrid, Tubitak and Ankara (Figure 4). In this way GPS allowed to insert the coordinates of this vertex and of other local reference points into the International Terrestrial Reference Frame ITRF2000, and then to insert every other local survey into this system.
The accuracy of the absolute positioning, after post-processing, came out at one centimetre level, certainly redundant compared to the common requirements of archaeological surveying.

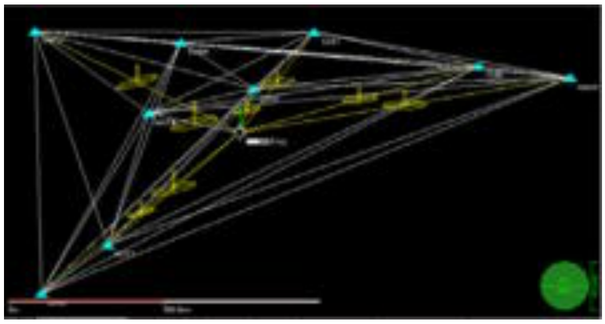


Figure 4. Scheme of the absolute
georeferencing geodetic net.

Other two stations, named MES_1 and MES_2, were connected to MES_0 vertex by a fast-static method; these points were used later as reference points in the topographical survey of the photogrammetric control points on the monastery south front.
In order to realize a complete, but expeditious, description of the wall structures belonging to the structures annexes to the church, a kinematic survey with data post-processing was then conducted, using the reference point MES_0 as master station; this choice permitted to insert also this survey into ITRF2000.
This operation was carried out with the important support of archaeologists, with the aim of choosing the more significant points for the structures interpretation and description (Figure 5). The Figure 6 shows the planimetry of the site, realized in a CAD environment connecting the points acquired by kinematic GPS survey, in according with a field map; the coordinates are UTM-WGS84.
Unfortunately the presence of some problems, due to the burial of a part of the complex and obstacles, didn't allow the whole survey of the area.

Figure 5. Kinematic GPS survey of the wall structures.

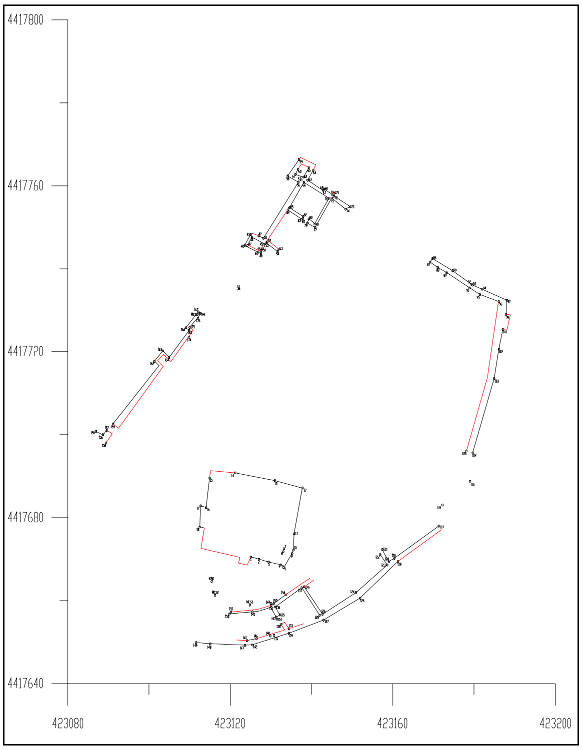


Figure 6. Plan of the site obtained by kinematic GPS survey.

2.2 Visual Reality technique

The Quick Time Virtual Reality system (QTVR) is a technique that permits the production of Visual Reality scenes by means of acquisition and generation of 360° panoramic digital images, each other connected to simulate an exploration of the interested area.
These multi-panorama scenes are deeply interactive and, being photographic based, offer a high qualitative level description; they allow to freely display the damage together with its eventually undamaged context, permitting a correct reading of the situation.
This system has been adopted from a long time by the authors in order to realize in a simple but effective way a photographic descriptive survey of large archaeological areas by a complex connexion of tens of panoramic nodes into a single scene embracing a complete site (e.g. Bitelli et al., 2003b).
This technique is cheap and presents an high simplicity together with fast esecution, so could be utilized also by not expert operators.
For a correct interpretation and management of the collected informations, every QTVR node that composes the scene, is usually georeferenced in the choosen absolute reference frame by means of GPS system; where the required accuracy is not stringent the use of a GPS palmar receiver could be suggested.
The monastery indoor and the neighbouring territory were explored by means of panoramic scenes each other connected (example in Figure 7), using for the acquisition the Fuji CoolPix and Canon PowerShot PRO 70 digital cameras.
This system permitted a field investigation to record the building state and a qualitative evaluation of the crack phenomenons that interest the monastery.
Figure 7 shows a view of the wooden altar inside the monastery, obtained by "image stitching" in order to product a complete panorama (360°) of the interior.

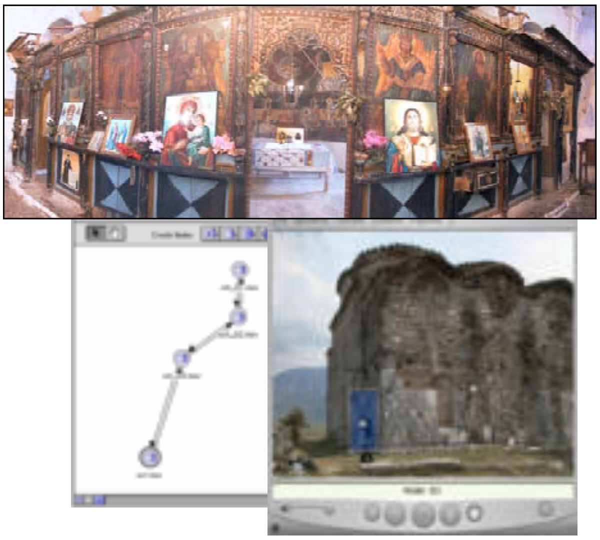


Figure 7. Building the QTVR scene: 360° node of the wooden altar inside the monastery, example of connexion among different nodes, final scene with hot spot related to the transition between exterior and interior nodes.

2.3 Close-range photogrammetric acquisition and data processing

A more rigorous metric documentation can be produced with close-range photogrammetry, that finds actually a large development with the diffusion of digital systems, both in acquisition and in processing. The applications in case of disaster are numerous and start from the simple documentation arriving to the structural and engineering analysis.
For the photogrammetric acquisition a small format semi-metrical Leica R5 camera was adopted, with 24 mm lens; the images were afterwards digitized at the highest resolution by KODAK Pro Photo CD system.
In the following, the survey performed with different approaches for the west and south facades of the monastery, and for the imposing basament that runs along the whole building perimeter, are described.
The west facade presents a flat morphology that well fits with a restitution by means of photogrammetric rectification; a classic topographical survey with Total Station was performed in order to determinate the coordinates of 5 control

points signalized on the building front by target tapes. The photomap of the facade was carried out after by RolleiMetric MSR 4.0; the selected pixel size of the final product was 2 mm. After evaluation of some check distances acquired on the field, the precision of the photoplan can be assumed consistent with 1:50.

The rectification processing, with resampling of original image and its projection on choosen plan (homographic transformation), requires a very short time. A rectified image represents a photographic metric representation that allows to understand various aspects of the object, as for example the colour, the materials, the presence of humidity spots or parts of damaged plaster, and every other information about the structure decay, as cracks and settlements.

On the other hand, it's also evident that the representation by means of vector plotting is a concise representation which points out the main structural elements, being also possible to separate the draw in thematic layers in according with the different architectural components.

The photoplan was then imported in Microstation/J CAD platform in order to realize a vector restitution.

A comparison of the two approaches can be clearly appreciated in figures 8 and 9, where both are presented in an hybrid product.

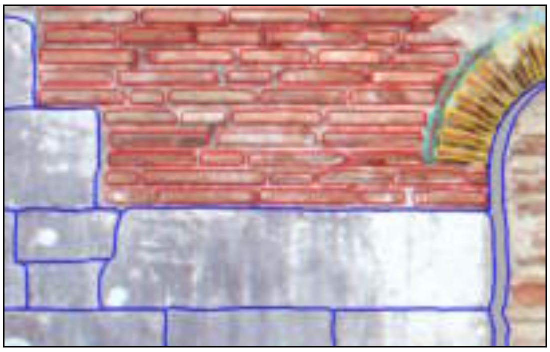


Figure 9. Particular of the vector thematic restitution.

The monastery south facade, for its morphology characterized by protrusions and bosses, is more suited for a stereoscopic restitution.

As ground control points (GCPs) were utilized 10 targets signalized on the front and surveyed by Total Station from two vertexes, placed on the two known vertex MES_1 and MES_2. It's so possible to insert also the photogrammetry restitution into ITRF2000, and have all the collected data geometrically consistent.

The photogrammetric processing was carried out by a Socet Set v5.2 workstation; in Figure 10 are reported the two images choosen for the elaboration, characterized by a 1:600 photoscale.

Figure 8. Photoplan of the monastery west facade with a partial vector drawing (reduction from 1:50 scale plot).

Figure 10. Stereo-pair used for stereoscopic restitution of monastery south facade.

After the interior and exterior orientation, performed respectively with an affine transformation and by a bundle adjustment analytical model (residual on control points at 1 cm level), the products that could be realized within a digital workstation are various: vector plotting, dense DTM in grid or TIN format, orthophoto and true-orthophoto.
A TIN surface model of the facade was generated by automatic correlation procedure, with a post-spacing of about 5 centimeters; this model was used for the production of a true orthophoto (Figure 11), by using bilinear transformation as resampling method; pixel size is 0.02 m; a slight DTM post-editing was necessary for the orthophoto production, with the introduction of top and base breaklines in correspondence of the central counterfort.

One of the problems in application of photogrammetry in emergency operative situation is the realization of the control points survey, not ever possible with a topographical classic survey, both because of logistic problems and building access and because of operations speed necessity.

In this case the problem of the topographical survey for GCP determination can be addressed in different ways and with different precision: using reflectorless total stations, reconstructing the 3D relative model and then scaling it by distance measurements, or in alternative adopting bi-cameras or pseudo bi-cameras devices where exterior orientation parameters are known. For this case study was successfully adopted the Cyclop system (Menci Software), that permits the acquisition of stereo-pairs using a calibrated base for a three-dimensional restitution without control points (Figure 12).

Figure 12. The system utilized for the basement acquisition

The system was used for the restitution of the marble basement, characterized by bas-reliefs; three stereo-pairs were acquired by semi-metric camera from different positions, and an example is shown in figure 13.
In order to realize a complete restitution of the whole basement, the three stereo-pairs were connected together carrying out an unique strip; the realization of this procedure was possible by using a local system defined by the central model as reference for the two side stereo-pairs, and realizing in Socet Set a bundle-adjustment triangulation.

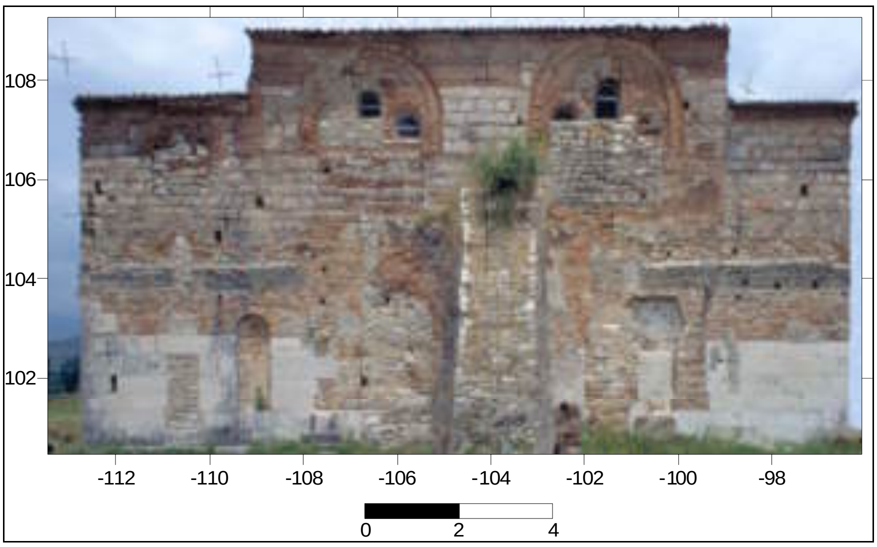
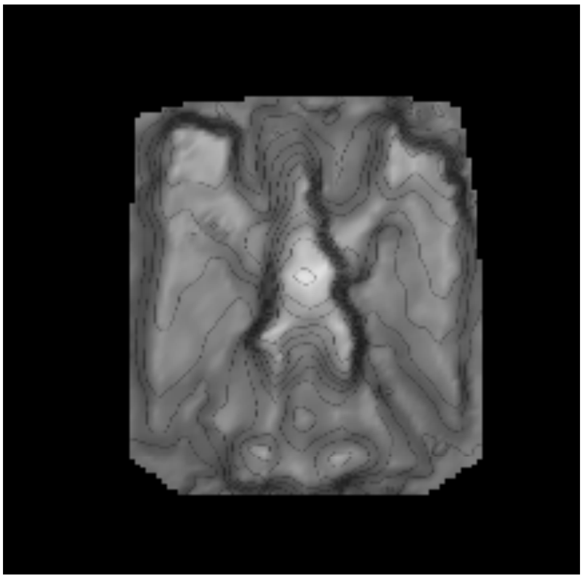


Figure 11. True-orthophoto of the monastery south facade.

Figure 13. Example of a basement stereo-pair.

As example of a possible final product, a dense DTM in grid format with a medium post-spacing of 3 cm was automatically extracted for the whole basament; about 20.000 points were calculated in less than two minutes.
Besides for the bas-relief representing the griffon a DTM with a post-spacing of 3 mm was extracted and a orthophoto (pixel size of 1 mm) was produced.
Figure 14 shows a 3d view of this model and the orthophoto.



a)

b)

Figure 14. 3D view (a) and orthophoto (b) of the griffon bas-relief.

3. CONCLUSIONS

The case study presented is an example of the potentialities offered by the modern geomatic techniques when integrated and coordinated. A quick survey of a complex structure can provide different products of high precision and reliability, all results are georeferenced in a unique system and are immediately useful for the development of an analysis of the building conditions, especially after a damaging event.

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