APPLIED 3D PHOTOGRAMMETRIC STUDIES FOR THE HISTORICAL HERITAGE OF EXTREMADURA (SPAIN)

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KEY WORDS: photogrammetry, heritage, rectification, 3D digital modelling.

ABSTRACT:

The region of Extremadura, in the southwest of Spain, contains three locations that have been declared UNESCO World Heritage Sites: the Old City of Cáceres (1986), the Archeological Ensemble of Mérida (1993), and the Royal Monastery of Our Lady of Guadalupe (1993). In the Geomatic Engineering and Urban Heritage Research Group of the University of Extremadura, we are working on a Regional Research Project entitled “Precision three-dimensional modeling, study of structural pathologies and virtual walks through the historical and cultural heritage of Extremadura”, in which we create 3D models of some emblematic buildings with regard to which actions are proposed for appropriate conservation and restoration. The procedure used to generate this type of model was in two phases: spatial data capture (topographical information using a TOPCON 7005i) and processing of the spatial information (creation of the 3D model, rectification and processing of the images and virtual recreation). For the work presented in this article, a technique was sought that would make use of very inexpensive techniques, namely a conventional digital camera and a reflectorless Total Station. Obviously, the final result is not the same as if we had used laser scanner digitalization or classical photogrammetry. As indicated in this article, the aqueduct of San Lázaro in Mérida and the Plaza de Santa María (Cathedral Square) in Cáceres were mapped in 3D by means of planes, with a precision of +/- 3 cm. Hence, in addition to making photo-realistic representations, it has been possible to determine the magnitudes (linear dimensions and surface areas) of the pathologies of both monuments (cracks, collapses, damp and deterioration of stonework).

1. INTRODUCTION

The Autonomous Region of Extremadura has a very abundant historical heritage. The most outstanding sites are the three UNESCO World Heritage Cities (UNESCO, 2009a):

1. The Royal Monastery of Santa María de Guadalupe (date of Inscription: 1993). The monastery is an outstanding repository of four centuries of Spanish religious architecture. It symbolizes two significant events in world history that occurred in 1492: the Reconquest of the Iberian peninsula by the Catholic Kings and Christopher Columbus' arrival in the Americas. Its famous statue of the Virgin became a powerful symbol of the Christianization of much of the New World.
2. The Archaeological Ensemble of Mérida (date of Inscription: 1993). The colony of Augusta Emerita, which became present-day Mérida in Estremadura, was founded in 25 B.C. at the end of the Spanish Campaign and was the capital of Lusitania. The well-preserved remains of the old city include, in particular, a large bridge over the Guadiana, an amphitheatre, a theatre, a vast circus and an exceptional water-supply system. It is an excellent example of a provincial Roman capital during the empire and in the years afterwards.
3. The Old Town of Cáceres (date of Inscription: 1986). The city's history of battles between Moors and Christians is reflected in its architecture, which is a blend of Roman, Islamic, Northern Gothic and Italian Renaissance styles. Of the 30 or so towers from the Muslim period, the Torre del Bujaco is the most famous.

There is an ever-increasing list of jobs which require the carrying out of virtual tours or the construction of three-dimensional models with the original texture of the objects mapped (by photogrammetry, laser scanner or Total Station). This increase in research and other projects can be observed, for example, in the various conferences organised by CIPA (the International Scientific Committee for Documentation of Cultural Heritage).

Another example is the announcement of an agreement between Google and UNESCO to provide virtual tours of several World Heritage sites (including the Old Town of Caceres). The agreement makes it possible for internet users to visit 19 of the 890 World Heritage properties via Google's Street View interface. The 19 sites are located in Spain, France, Italy, the Netherlands, the Czech Republic and the United Kingdom. Street View provides nearly spherical (360° horizontal and 290° vertical) panoramic views taken by cameras mounted on vehicles. Once obtained, these images are overlaid on Google Maps' satellite views - the process can take several months. When the specially-equipped cars cannot reach sites to be photographed, tricycles are used (UNESCO, 2009b).

The chief inconvenience of this type of information is its low quality relative to the results obtained by means of geomatic techniques.

In recent years, techniques applied for carrying out architectonic surveys include photogrammetry (standard shots or convergent shots), laser scanners, and Total Stations “without prism” (García, 2005) (Núñez et al., 2006). This diversity of techniques gives businesses involved in producing architectonic

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cartography the possibility of availing themselves of a wider range of choice so as to optimise financial outlay, results, etc.
Since 2004, in the Geomatic Engineering and Urban Heritage Research Group (IGPU), we have been working on various cartographic projects in the old town of Cáceres (Durán & Sanjosé, 2008). In addition to photogrammetric surveys of the most emblematic buildings (the Torre de Bujaco, Casa del Sol, and Episcopal Palace), we have performed topographic surveys and photographic captures for the restoration of façades on the Aqueduct of San Lázaro in Mérida and Plaza Santa María (Cathedral Square) in Cáceres (Fig. 1).

Figure 1. Aerial view of the Old Town of Cáceres and the area of the Plaza de Santa María.

2. METHODOLOGY

Among the different photographic techniques that can be employed to obtain three-dimensional digital models of buildings, the most common are standard shots and convergent shots. However, in some cases it is also possible to use projective two-dimensional transformations (or rectification of photographs). This last technique has to be applied on flat elements, such as façades of buildings without balconies, flat walls, paintings, etc. By its nature, it permits the generation of 3D models of historic buildings in a short period of time and at a relatively low cost, with a precision sufficient for creating an inventory of their state of conservation and of the principal pathologies from which the building might suffer: cracks, damp, erosion, dirt, and so on.
The procedure used to generate this type of model was as follows:

2.1 Spatial data capture.

2.1.1 Taking of photographs: The façades of the buildings were photographed, ensuring that the whole façade was captured in the photo. In cases where this was not possible, a composite was created by means of a mosaic of images. In addition to photos of the façades, all the details that make them up were photographed: window recesses, balconies, roof eaves, etc. The photographs were taken with a 35 mm 12.80 Megapixel Canon EOS 5D digital camera.

2.1.2 Topographic data capture: a Topcon GPT 7005i Total Station "without prism" was used. This type of station permits the capture of different points without the need for a prism. One of the features of this Total Station is that it makes a detailed photograph of every point measured, and also makes panoramic photographs of all the points. By this means it has been possible to capture a large number of points without need of making a sketch (Fig. 2).

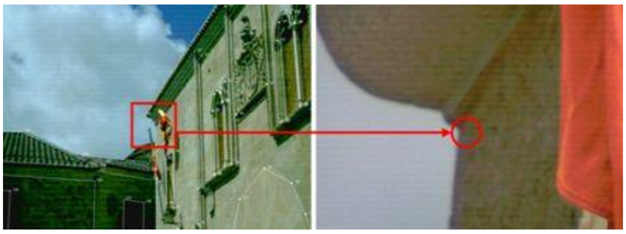

Figure 2. General shot and detail shot taken by the GPT 7005i Total Station, with the location on the building of the point captured.

2.2 Processing of the spatial information

2.2.1 Creation of the 3D model: To obtain the 3D model, TCP-MDT design software was used under license from Autocad. The procedure was as follows: joining of the points of the model using 3D polylines, distribution of groups of polylines into different layers, creation of surfaces on the wire frame and adding of textures to the various surfaces (Fig. 3).
Once all the façades have been corrected and defined, we proceed with their extrusion as indicated by the depth of each recess: windows, doors, balconies, cornices, architectural details, etc.

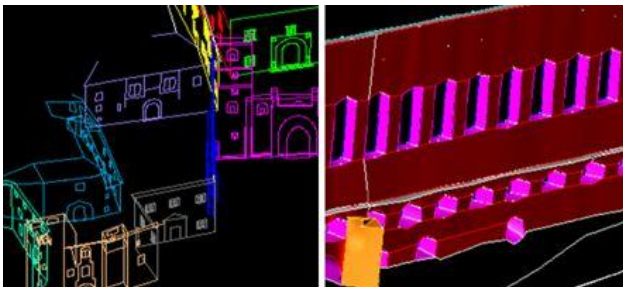

Figure 3. Representation of the façades of the Plaza Santa María (Cáceres) and creation of the surfaces on the Aqueduct of San Lázaro (Mérida).

2.2.2 Rectification and processing of the images: ASRix software was used for the rectification of the images and Photoshop for their processing. The procedure followed was: rectification by means of a projective two-dimensional transformation between the plane of the photograph and that of the object (the surface generated on Autocad); adding of the rectified photograph as texture onto the 3D model. At this point a 3D model has been obtained of the architectural element as it was found at the moment of taking the photograph. However, we have also detected and corrected such unwanted features of the photograph as vegetation, electrical cables, graffiti, dampness, etc (Fig. 4). For those photographic corrections which indicate actions required for the conservation and restoration of the heritage site, an "action sheet" has been created by way of inventory. This is one of the most important points in the work undertaken because the precision of this work permits a true measurement of the affected surfaces (graffiti, damp problems, etc.), risks of collapse (measurement of cracks, inclination of the façades), and other pathologies.

Figure 4. Original and corrected photographs.

2.2.3 Virtual recreation: Finally, for the creation of the videos the 3D Studio Max programme was used, and for the audio the Camtasia Studio programme. Virtual tours have, besides other advantages, two especially useful functions: those people who cannot access the building for any reason (restoration, distance, disability, etc.) can take a "virtual walk" without leaving their own home; and in addition, it is possible to create a 3D model and a virtual tour of the building in order to make an analysis of how it would look after performing specific actions of conservation on it (cleaning of facades, repair of dampness, removal of buildings of little historical interest, and so on). In order to be able to create the virtual tour, we have first had to undertake a process of generalisation so that the hardware can "move" all the images. Examples of this generalisation are treating the arches of the aqueduct of San Lázaro as polylines of 5 points instead of as rounded arcs, or inserting a fixed image for the sky. However, this generalisation does not reduce the precision of the mapped elements. The final results are shown on our open access webpage: http://www.unex.es/igpu (Fig. 5).

Figure 5. Examples from the video of the Plaza de Santa María and of the Aqueduct of San Lázaro.

3. RESULTS

The technique employed permits the generation of 3D models with a precision sufficient for historical heritage conversation work. With respect to the work undertaken on the Plaza de Santa María and the Aqueduct of San Lázaro, we have been able to create an inventory of numerous architectural defects caused by the passage of time, the weather, and human actions upon the heritage sites. Specific measurements of the pathologies detected can be obtained (linear dimensions and surface areas). We may take the following by way of examples:

Plaza Santa María

Cracks and fissures were detected in the Palace of Hernando de Ovando and in the Episcopal Palace (Fig. 6). In addition, damage produced by damp was detected in the Palace of Hernando de Ovando, in the Palace of Diputación and in the Church of Santa María (Fig. 7), and deterioration of the stonework in various cases (Fig. 8).

Figure 6. Cracks in the Episcopal Palace.

Figure 7. Damp in the Palace of Diputación and the Church of Santa María.

Figure 8. Deterioration of stonework in various cases.

Aqueduct of San Lázaro.

The aqueduct suffers from numerous pathologies. The most common are cracks and fissures, as may be appreciated in figure 9, as well as damp and deterioration of the stonework (Fig. 10). Given its antiquity (1st, 2nd, and 16th centuries), we also encounter detached stonework and collapses (Fig. 11).

Figure 9. Some of the cracks detected in the Aqueduct of San Lázaro.

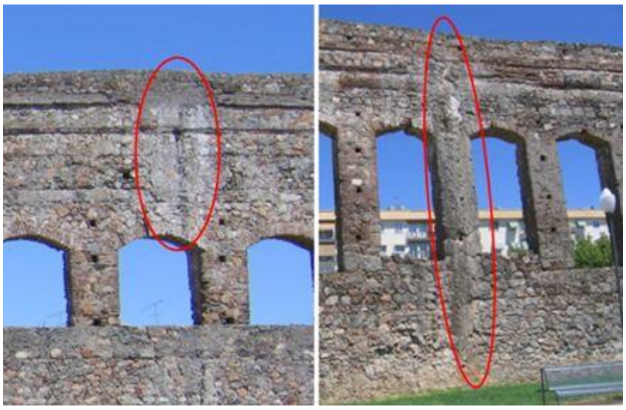

Figure 10. Deterioration of stonework in the aqueduct.

Figure 11. Detached stonework.

4. CONCLUSIONS

For the work presented in this article, a technique was sought that would make use of very inexpensive techniques, namely a conventional digital camera and a reflectorless Total Station. Obviously, the final result is not the same as if we had used laser scanner digitalization or classical photogrammetry. In the case of a laser scanner, a great number of points is obtained, which generate large tables of data that require more time to process. Hence for jobs where a large quantity of information is not required, the use of a reflectorless Total Station allows us to obtain acceptable results.
In addition to the technical means used in the field (camera and total station), we have used computer programmes that are affordable (ASRix) or widely available in the heritage profession (Autocad and 3D Studio).
As indicated in this article, the Aqueduct of San Lázaro in Mérida, and the Plaza de Santa María (Cathedral Square) in Cáceres were mapped in 3D by means of planes, with a precision of +/- 3 cm. Hence, in addition to making photo-realistic representations, it has been possible to determine the magnitudes (linear dimensions and surface areas) of the pathologies of both monuments (cracks, collapses, and damp).
At present we are working in the Plaza Mayor (Main Square) and during 2010 we anticipate beginning work in the Plaza de San Jorge, both in Cáceres. Furthermore, the publication of our results on a new webpage is being planned from our website: http://www.unex.es/igpu.

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Acknowledgements

We express our gratitude to the Junta de Extremadura for the financing of the project PRI09A025 (Regional Research Project).