

# COMPARISON OF DIFFERENT APPROACHES TO CREATE ARCHITECTURAL ARCHIVES

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## Commission V, WG 4

**KEY WORDS:** Architecture, Photogrammetry, Analysis, Archiving, Accuracy, 3D urban models.

### ABSTRACT:

The architectural heritage is continuously at risk due to the threat of multiple catastrophes caused by human and/or natural interference. The importance of architectural archives to help preserving the historical monuments is thus obvious and urgent. Architectural archives can be created by means of terrestrial photogrammetry, using distinct approaches. These approaches relate mainly to the selection of the data acquisition equipment - analogue versus digital cameras and among these, metric versus non-metric cameras – and the data processing and information extraction techniques – stereoscopic versus monoscopic convergent multi-image techniques. The selected technique has implications on the instrument used to process the data, i.e., dedicated (photogrammetric workstation) versus standard computer, which influences accuracy and greatly the costs.

In this study we create architectural archives of one Portuguese church with the referred techniques, by using the *Photogrammetric Image Station SSK Pro* from Intergraph and the software *PhotoModeler*. The data to create the archives are collected with analogue and digital cameras as well as metric and non-metric cameras. The archives are made up of the photographs/images acquired, the control points, and 3D models in the vector form as well as rendered with rectified images. The church is inserted in its surroundings with the help of 3D urban models. These are created with aerial images and aerial photogrammetry. Multi-media techniques are used to promote the divulgation of the church archives through the Web.

The archives are also compared in terms of accuracy. The main conclusion is that architectural archives, of moderate detail, created with the *Photomodeler* and digital non-metric cameras fulfil the user requirements.

## 1. INTRODUCTION

Architectural archives of monuments and historic buildings, complemented with geographical information of the surroundings, are a valuable source of information to preserve, reconstruct and rehabilitate the architectural patrimony. Existing a preoccupation and determination in protecting the architectural patrimony from degradation, fire, and other disasters, architectural archives have to be considered a civil necessity of defence in the combat against its extinction.

At the international level, and reflecting a great preoccupation in protecting the architectural patrimony, several organizations were founded. Amongst others it can be mentioned the *International Committee for Architectural Photogrammetry* (CIPA), established by the *International Council of Monuments and Sites* (ICOMOS) in collaboration with the *International Society of Photogrammetry and Remote Sensing* (ISPRS), which work, with UNESCO, on the elaboration of the World Patrimony List. These organizations established that the architectural patrimony to be protected and restored needs to be fully measured and documented, Photogrammetry being the means by excellence to do that. The process of measurement and documentation includes those of the surroundings. In this context, when the architectural patrimony is located in an urban area, it is necessary to create a 3D model of the surroundings.

This addition widens the range of users and promotes the connection between preservation of patrimony and urban administration.

Finally, the use of multi-media techniques to present and visualise the geographic data contributes to enrich the architectural archives inserted into the 3D models. New techniques for data acquisition, processing, extraction, modelling and visualisation, providing new means for the creation and divulgation of geographic information, become a great support to the preservation of the architectural archives in areas such as historical tourism and urban planning.

This article presents in a succinct manner the work, in the form of a study case, carried out to produce architectural archives using different techniques. These techniques concern not only the extraction phase (monoscopic versus stereoscopic photogrammetry) but also the acquisition phase (analogue versus digital cameras). The obtained results are also compared in terms of final accuracy. In order to introduce the reader to the basic concepts involved, we start by defining architectural archives and 3D urban models. Some visualisation techniques are also presented.

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## 2. ARCHITECTURAL ARCHIVE

An architectural archive concerns the detailed documentation of monuments and buildings, which includes, in addition to the descriptive information (e.g. history, style), the precise geometry, the description of their present status, and the survey of facades. With the present state-of-the-art, it can be said that an architectural archive is a digital data base, geometric and alpha-numeric, of a monument/building associated with its 3D model. According to Carbonell (1989), although the architectural archive belongs to the so-called architectural precision survey, it is nonetheless a recording of a more generalist frame, for, being less detailed, allows a systematic documentation of the main monument/building. Figure 1 shows one of the records (elevation) that makes part of an architectural archive.

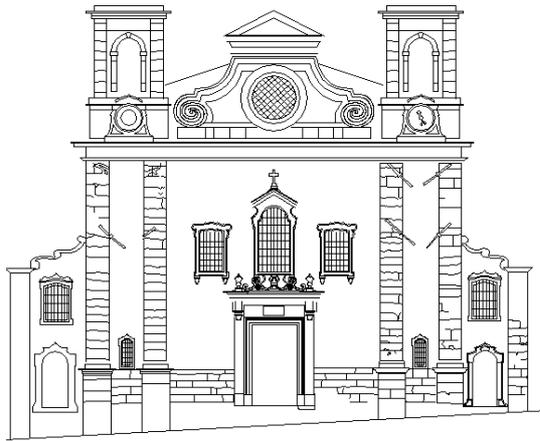


Figure 1. Part of an architectural archive (elevation of a church)

An architectural archive is important from various points of view: its drawings can be used as a tool when changes or restoration of the monument/building are needed (Dallas, 1980); the recording of the monument/building is fundamental when reconstruction is needed; it is also crucial for historical studies (Carbonell, 1989); it may also be used to organize and order existing data, facilitating the reconstruction of the past of the monument/building, its interpretation and recording of knowledge (Arnold, 2000).

An extra dimension added to the architectural archives is given by modelling of the objects. 3D models allow to view the objects from several view points, some difficult or even impossible to attain in the real situation due to the object itself and/or its surroundings (El-Hakim *et al.*, 2002). Furthermore, they allow a virtual interaction with the object (visualisation of changes for helping in decisions); creation of virtual museum and tourism, allowing, for example, the virtual entrance in buildings that are closed for security reasons.

To create an architectural archive there are several requirements, including the scale and precision which may vary from 1:50 to 1:100 and from 2 to 5 cm, respectively (e.g. Carbonell, 1989; Scherer, 2001). Techniques that may guarantee these requirements are Photogrammetry, and more recently Terrestrial Laser Scanning.

## 3. 3D URBAN MODELS

3D urban models are a three-dimensional representation of the urban environment, which is a simplification of the more

general environment. It represents buildings as well as other man-made structures. To improve the visual appearance and to make it more realistic, certain details need to be added to the geometric models and, if possible, other types of functions (such as virtual walks) and information. In this way, the geometric part of the models has to be handled with visual and animation techniques.

3D urban models are used for several applications such as urban planning and management, architecture, virtual reality, simulation studies (e.g. telecommunications, catastrophes), tourism, and environmental impacts.

The procedure to create 3D models can be divided according to Figure 2: planning and acquisition of data, data processing, and modelling and rendering. By modelling we understand the geometric reconstruction of the object, whereas by rendering we mean modelling of textures and light effects to make the models more realistic during visualisation.

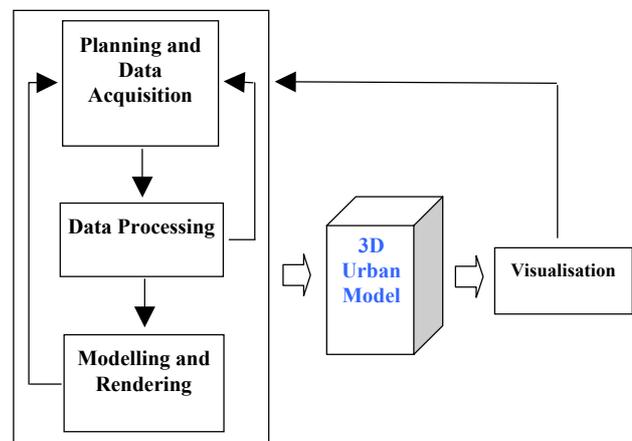


Figure 2. Main processes to create 3D urban models

Obviously, the creation of a 3D model is dependent of its intended use - for virtual tourism the geometric precision is less important than the visualisation effects, whereas for some studies both geometric precision and photorealistic effects are important. This intended use of the model has to be taken into consideration in the planning phase.

## 4. VISUALISATION

The visualisation of a 3D model, be it of an object or urban, aims at valorizing the model through its presentation and by making its divulgation attractive and available to a great number of users.

Visualisation may be done with simple images, or, as it is done in this study, using more sophisticated means that allow a greater closeness to reality. Animations and the creation, for example, of a multi-media recording on a CD-ROM are another efficacious means of divulging the 3D models and associated information (e.g. location and historical description of the surroundings), contributing to the public awareness of the cultural patrimony.

Visualisation is thus the ultimate stage by which the 3D models are made known and available for several applications. This implies that the 3D model's format should comply with international standards, allowing for interactivity, as for example the language VRML (*Virtual Reality Modelling Language*) for distribution on the *Internet*.

The software to produce 3D models must allow their storage in a format compatible with the software used for visualisation. It should be noticed that the great majority of software to produce 3D models also includes tools that allow their visualisation from several view points, their animation (walk-throughs or fly-overs) and even the production of some short films (e.g. in AVI format).

There are several software packages available on the market, some even for free, to visualise 3D models. Some packages allow the insertion of additional information such as documents of text, *hyperlinks*, music and films. Different software or modules may be used according to the model type (city, terrain or object), and the pretended visualisation (animation, walk-throughs, fly-overs, virtual reality or static visualisation). To attain an adequate selection it is advisable to make some prior tests with data sets of different sizes.

## 5. CASE STUDY

### 5.1 Objectives

The main objectives of the work address:

- Use of Photogrammetric techniques for recording of cultural patrimony. To this end, it is produced an architectural archive consisting of several products, such as images and control points, elevations of facades, and a 3D model rendered and also in vector format;
- Production of a 3D urban model to be inserted into an architectural archive;
- Comparison, in terms of performance and precision, of two photogrammetric techniques (monoscopic convergent versus stereoscopic) and of different photographic cameras for data acquisition.
- Production of a multi-media CD-ROM containing all the relevant information recorded of the patrimony and its surroundings.

### 5.2 Study Area

The work was carried out for the mother church of Oeiras (Figure 3a), situated in the old part of the town of Oeiras close to the capital of Portugal, Lisbon. The church dominates the town centre and its immediate surroundings. These surroundings are complex due to a large number of roofs (Figure 3b), which are difficult to interpret and, thus, require generalisation.



Figure 3. a – Mother church of Oeiras; b – surrounding urban tissue

### 5.3 Resources

The resources described here concern the software and instruments used, and are listed in Tables 1 and 2.

Task	Instruments (details in table 2)	Software
Architectural Archive	Photographic Cameras Scanner Photogrammetric Station Total Station	Calibration of cameras: Camera Calibrator
3D Urban Model		Image Processing: Image Analyst and PhotoShop
Visualisation		Editing: AutoCad
Analyse of Results		Stereoscopic Photogrammetry: Image Station SSK Pro Convergent Monoscopic Photogrammetry: PhotoModeler 4.0 Geometric Modelling: Microstation Visualisation: Microstation, Cosmoplayer and Macromedia Director Statistical tests: Excel

Table 1. Resources: instruments and software

Instrument	Branch Model	Focal distance (mm)	Pixel size (µm)	Image Format (mm)	Resolution
Digital Metric Camera	Rollei D7Metric	7.5	3.5	8.9×6.7	2552×1920
Digital Non-metric Camera	Nikon Coolpix 775	7.69	4.5	6.8×5.1	1600×1200
Analogue Semi-metric Camera	Leica R5	35	15	36×24	2445×1583
Analogue Non-metric Camera	Leica R8	28	20	36×24	1800×1200
Instrument	Branch	Geometric Resolution (ppp)	Model	Radiometric Resolution (bits) (intern/extern)	
Scanner	Epson	1600×3200	1640XL	42/42	
Instrument	Branch Model	Linear Resolution	Angular Resolution	Specificities	
Total Station	Sokkia Set 600	2mm+2ppm	5''	Distance by Laser	

Table 2. Technical characteristics of the instrumentation used

### 5.4 Data Acquisition

Data acquisition concerns the preparations for the creation of the architectural archive, and addresses the planning and acquisition of the photographs/images, including camera calibration, and of the control points. In the following sections these two processes will be discussed in more detail.

#### 5.4.1 Planning and Acquisition of photographs/images

Planning of the photographic survey is a crucial phase in the overall process of creating the architectural archive for it allows an appropriate coverage of the object at a scale that is adequate to attain the required accuracy. It is done in different ways in accordance with the technique to be used to extract the required information. In the following, the planning phase is presented for the extraction process with stereoscopic and monoscopic photogrammetric techniques, respectively. For both techniques, the medium photo scale has to be between 1:400 and 1:600 to

satisfy the requirements for information extraction at a scale of 1:100.

**5.4.1.1 Stereoscopic Photogrammetry:** planning for photographic acquisition is done in a similar way as for the so-called normal case (Karara, 1980). Thus, parameters as the base, distance to object, and model size are estimated. Their estimated values permit to draw the photographic survey plan (Figure 4), which also shows the locations of the camera positions.

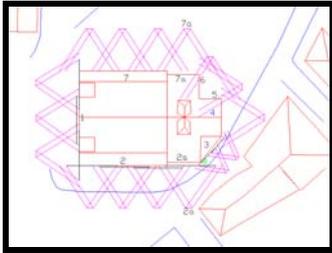


Figure 4. Plan of the photograph survey (stereoscopic)

**5.4.1.2 Monoscopic Photogrammetry:** in this case, there are a set of empirical rules to draw the plan of the photographic survey (Figure 5). For example, the angles between the optical axes of neighbouring cameras must be approximately 90°; and at least three photographs have to be acquired of the same object – one in a central position and two on either side, with sufficient overlap to have the same details photographed from multiple view points.

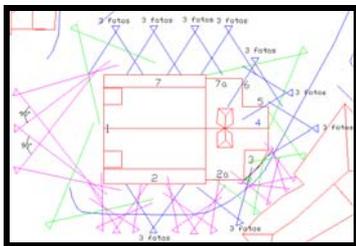


Figure 5. Plan of the photograph survey (monoscopic)

#### 5.4.2 Planning and acquisition of control points

Control points must be distributed in accordance to the information extraction technique used. The control points for the stereoscopic technique were selected around the limits and centre of photographs, whereas those for the monoscopic technique were selected in a regular manner around the object. The control points may also be artificial or natural. The latter should be distinct features of the object, which in our case are represented by corners of windows, ornaments and crosses. They were measured in a closed polygonal set-up, using a total station with a laser distance measuring device.

### 5.5 Architectural Archive

The complete architectural archive was produced by means of the monoscopic convergent technique and a calibrated non-metric digital camera. This choice was based on the test results presented in section 5.8, which permitted to conclude that it was the best choice in terms of quality/price relationship. Nonetheless, as the above referred comparative analysis

addresses the two photogrammetric techniques, the related processes are briefly resumed in the following sections. These processes are carried out with the ImageStation SSK (stereoscopic photogrammetry) and with the PhotoModeler (monoscopic convergent photogrammetry).

**5.5.1.1 ImageStation SSK Pro:** the stereoscopic images were oriented using the standard procedures: interior, relative and absolute orientation (single model), or interior and multi-photo orientation (block of photographs). As a requisite of the software, the images had to be resampled afterwards to the epipolar geometry needed to perform the stereo plotting of the facades. Stereoscopic photogrammetry is more appropriate for highly detailed objects, which is in general not the case for the Oeiras mother church. Image acquisition is more demanding since the normal case is difficult to maintain in order to cover the whole object. Furthermore, a trained operator is required to extract the 3D information from the stereoscopic images. Therefore, the stereoscopic approach is not as user-friendly as the monoscopic one, but it is more appropriate for the detailed restitution of the complex shapes so often found on many heritage monuments.

**5.5.1.2 PhotoModeler:** the approach adopted in this software is basically different from the previously mentioned since it is based on monoscopic measurements that can be carried out using a standard computer. The images are oriented identifying common points between 3 to 4 photographs, and related to an absolute system using the control points referred in section 5.4.2. The tools to assess the quality of the solution are used for continuous monitoring of the quality of the process while inserting new images and control points to plot new details. Monoscopic photogrammetry is generally considered to be a rather simple technique that can be used by non-photogrammetrists but is appropriate only for the recording linear features and details of limited complexity. Some results of this processing are shown in Figure 1 (elevation of facade), Figure 6 (3D model in vector format) and Figure 7 (3D model rendered with rectified images).

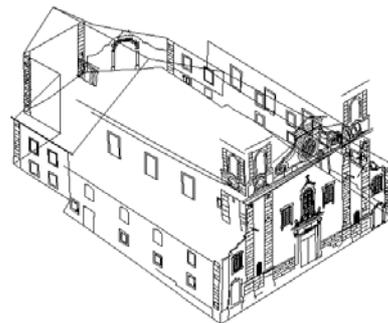


Figure 6. Perspective NW of the 3D model (vector) of the Oeiras mother church



Figure 7. Perspective SW of the 3D model of the Oeiras mother church, rendered with rectified images

### 5.6 3D Urban Model

The steps to create a 3D urban model are shown in Figure 2. Data acquisition refers to the acquisition of the basic input, such as points and lines describing the roofs of buildings and a Digital Terrain Model (DTM). These are extracted/produced by means of photogrammetric restitution of aerial photographs. Modelling was done by surfaces with MicrostationJ. Figure 8 shows the basic information projected onto the DTM. The surfaces representative of each wall are created afterwards. Rendering concerns mapping of textures using a rendering algorithm. To make the model realistic, the textures are made with rectified images of the facades of the objects. The rendering algorithm used allows to add to the model some characteristics such as illumination, transparency and colour. Figure 9 shows a part of the 3D model of the Oeiras mother church after rendering.

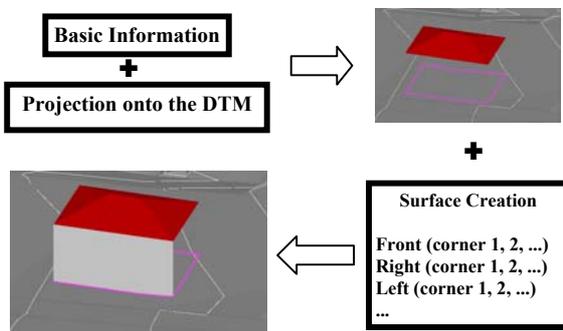


Figure 8. Process of modelling (geometric)



Figure 9. Part of the 3D model of the Oeiras mother church and its surroundings

### 5.7 Visualisation

Visualisation is a complement to the architectural archive, as a means of divulging it. In addition to the various images that

may be extracted to visualise results, animations were created with Microstation. These are walk-throughs around the church and its surroundings, which were recorded on a CD, integrated with other products such as the recorded facades, the 3D urban model and information about the Oeiras church history.

### 5.8 Comparative Analysis– Stereoscopic Photogrammetry versus Monoscopic Photogrammetry

The comparative analysis between the two photogrammetric techniques was carried out by computing statistical values for the residuals between the coordinates of the points measured by the referred techniques and those of the control points. A total of 100 control points were chosen randomly and their coordinates measured with precise topographic techniques. The points were measured on images acquired with the different cameras (Table 2). The computed statistical values refer to the Root Mean Square Error (RMSE), the standard deviation and the maximum and minimum residuals (in X, Y and Z). Because of apparent incompatibilities between the digital metric Rollei camera and the photogrammetric workstation, which require further investigation, Table 3 lists only the values computed for the metric camera Leica R5 and the stereoscopic technique.

	Leica R5		
	X (cm)	Y (cm)	Z (cm)
RMSE	2,3	2,43	4,0
Standard Deviation	2,1	2,4	4,0
Maximum Residual	5,4	6,1	6,5
Minimum Residual	-5,6	-5,2	-5,7

Table 3. Statistical results for the residuals obtained with a metric camera and the stereoscopic photogrammetry (ImageStation SSK Pro)

Tables 4a and 4b list the results for the monoscopic photogrammetry using all the cameras, and Table 5 shows which comparisons were carried out between the results obtained with the different cameras and photogrammetric techniques. These comparisons involved two statistical tests, i.e., the Student-t test and the F-test. Whilst the former allows comparison of means, the latter permits comparison of variations.

	Rollei			Nikon		
	X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)
RMSE	1,5	1,6	1,56	2,3	2,4	2,3
Standard Deviation	1,5	1,6	1,5	2,3	2,4	2,3
Maximum Residual	3,1	2,9	3,5	4,3	4,1	4,0
Minimum Residual	-3,6	-3,4	-2,5	4,2	-4,0	-3,9

Table 4a. Statistical results by using PhotoModeler and the digital cameras Rollei and Nikon

	Leica R5			Leica R8		
	X (cm)	Y (cm)	Z (cm)	X (cm)	Y (cm)	Z (cm)
RMSE	4,6	3,5	4,9	4,1	3,9	3,5
Standard Deviation	4,1	3,5	4,9	3,9	3,8	3,4
Maximum Residual	8,9	8,3	8,8	7,1	7,7	7,5
Minimum Residual	-6,4	-7,1	-8,1	-7,8	-8,0	-8,4

Table 4b. Statistical results by using PhotoModeler and the analogue cameras Leica R5 and Leica R8

	MA S	MD S	MA M	MD M	NMA M	NMD M
MA S		•	•	•	•	•
MD S			•	•	•	•
MA M				•	•	•
MD M					•	•
NMA M						•

Table 5. Scheme of comparisons between the different cameras (MA – metric analogue, MD – metric digital, NMA – non-metric analogue, NMD – non-metric digital) and the photogrammetric techniques (S–stereoscopic, M–monoscopic)

The results show that the performance of the digital cameras Nikon and Rollei is similar, and better than that of the analogue cameras Leica R5 and Leica R8. These 2 analogue cameras have a similar performance with stereoscopic and monoscopic photogrammetry. The most accurate results are obtained with the Rollei camera, followed by the Nikon camera. The accuracy obtained with the cameras Leica R5 and Leica R8 and monoscopic photogrammetry are comparable, although the Leica R8 camera gives somewhat more accurate results in Z. This higher accuracy in Z can be justified by the greater convergency of the photographs acquired with the Leica R8. The results in X and Y obtained with the Leica R5 camera and stereoscopic photogrammetry are more accurate than those obtained with the Leica R8 camera and monoscopic technique. To resume, the accuracy of the results obtained with the 4 cameras and the two photogrammetric techniques is within the limits of the user specifications for an architectural archive, i.e., 2 to 5 cm.

## 6. CONCLUSIONS

To conclude, Photogrammetry is as expected an excellent means for accurate recording of architectural patrimony in the form of an architectural archive. In this way, an architectural archive is of fundamental importance for the preservation of the patrimony. This preservation as well as the divulgation of the patrimony and its surroundings is well-served with the 3D urban models.

With respect to the photogrammetric techniques and the photographic cameras it can be concluded that the monoscopic technique allows for a simpler data acquisition process than the stereoscopic one (i.e., for the so-called “normal” case).

Information extraction is a time-consuming process in the case of both techniques. Nonetheless, with the monoscopic technique, the extraction of information from facades with complex details is rather difficult. The existing software based on the monoscopic technique has the advantage of allowing as well the production of 3D models rendered with the rectified images. The tests show that a standard digital camera, together with relatively simple software based on the monoscopic technique, allow the production of architectural archives at scale 1:100 with a good price/quality relationship.

## REFERENCES

Bourdakis, V., 1999, On Developing Standards for the Creation of VR City Models., *Modeling & City Planning*.

Carbognell, M., 1989, Architectural Photogrammetry in *Non-topographic Photogrammetry*, Ch. 19, pp. 321-347, Second Edition, American Society For Photogrammetry and Remote Sensing, (USA: H. M. Karara, Science and Engineering Series).

Dallas, R. W. A., 1980, Architectural and Archaeological Recording in *Developments in Close Range Photogrammetry – 1*, Ch. 5 pp. 81-116, (London: K. B. Atkinson, Applied Science Publishers, Ltd.).

El-hakim, S.F., Beraldin, J. A., Picard, M., 2002, Detailed 3D Reconstruction of Monuments Using Multiple Techniques In CIPA WG6 International Workshop: *Scanning for Cultural Heritage Recording*, Corfu, Greece, 1-2 Set.

Scherer, M., 2001, About the Synthesis of Different Methods in Surveying, Proc. of International Workshop on *Recreating the Past – Visualization and Animation of Cultural Heritage*, Ayutthaya, Tailândia.

## ACKNOWLEDGEMENTS

The authors are grateful to *Municipia* for lending the aerial photographs and the orientation data, to the *Instituto Superior Técnico* for lending the semi-metric digital camera, and to *Topométrica* for lending the total station.