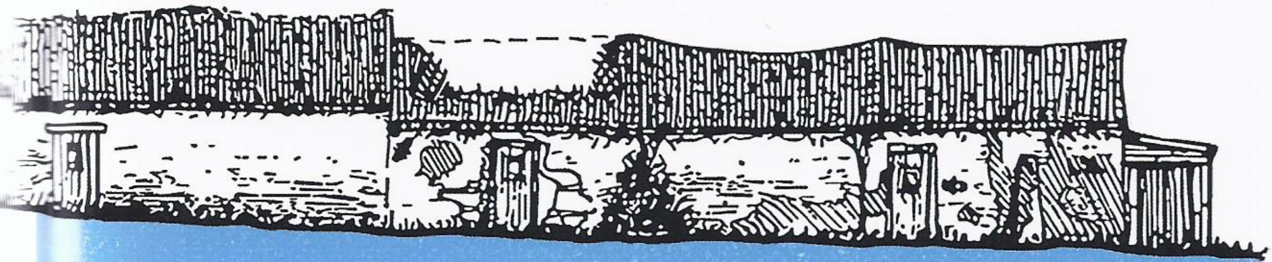

VERNACULAR HERITAGE AND EARTHEN ARCHITECTURE

CONTRIBUTIONS FOR SUSTAINABLE DEVELOPMENT

EDITORS: MARIANA CORREIA, GILBERTO CARLOS & SANDRA ROCHA

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Three-dimensional reconstitution of an ex-place: The submerged Vilarinho da Furna, Portugal

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ABSTRACT: One can find, in our planet, many places that have disappeared or were destroyed for many various reasons. We call them ex-places. Our case study, the village of "*Vilarinho da Furna*" in Portugal, submerged in 1972 by a dam construction, is one of such ex-places. This paper describes a methodology for data collection and 3D modeling from extant graphic documentation of a place that no longer exists. From that a 3D reconstruction was attempted. We start by describing what sources of information were considered and what concerns were taken into account. Then we explain the modeling and integration strategies followed. We end with a discussion of the methodology underlining the framing principles adopted. The aim was to revive this ex-place, reconstructing its form, size and scale, contributing to its rescue from oblivion.

1 INTRODUCTION

Today, Man's role as a profound transforming agent of the built and unbuilt global Heritage does not raise much doubt. His creative capacity can easily be compared to his destructive capacity, both proving to be equally effective.

Therefore, it is not surprising that the text of the Convention concerning the protection of the world cultural and natural Heritage (UNESCO 1972), after listing the types of places and objects to be considered as cultural Heritage, then enumerates the reasons that may lead to their disappearance, many of which are directly or indirectly due to human action.

In spite of good intentions and of all efforts made to protect and preserve the Heritage of mankind, the threatening factors keep on evolving to effective destruction events, often leading to its material disappearance. Besides that, and although the concern with the Heritage preservation is an old issue, it is a relatively new priority, which has been ignored by many centuries of bad practices, what, consequently, resulted in "irreparable" losses for the History of Mankind, specially the ones that were not documented or described in any way.

One of the main objectives of the practical work carried out within the scope of the integrated Master Thesis in Architecture at the Faculty of Architecture—Technical University of Lisbon, entitled "Modeling the past. A methodology for a three-dimensional reconstitution of a place based on graphic documentation and archive images", was to try to understand the extent of loss that can be "repaired", i.e., if it is possible to achieve a "virtual restoration" of the disappeared object, and what possible paths we have to go through in search of this goal. The work developed was based on the pertinence of trying to establish and understand possible links between new techniques and methods and archive sources of information, expecting to produce new documentation that may open up fresh prospects on a reality that is not accessible today, nor will ever be.

As working targets, we set several objectives related with the devising of a methodology to achieve the reconstitution and three-dimensional modeling, up to a building scale, of an inaccessible and non-existent ex-place, using for this purpose all the graphical documentation and static or moving images available.

It was our concern to describe all the sources and procedures followed since we believe that the extent to which authenticity can be judged relies on the reliability of the documentary sources (ICOMOS 1994) and we also believe that it is important to declare how the information present in those sources was used. Following this principle, alternative solutions are always possible, and more important, comparison can be done. This is one major principle declared in the London Charter for computer-based visualization of cultural Heritage (AAVV 2009).

2 CASE STUDY—THE SUBMERGED VILLAGE OF VILARINHO DA FURNA

Considering the objectives set for this task, we have chosen for the study object a disappeared place, non-existing today, but which did exist in the past, i.e., a inaccessible ex-place, the submerged village of Vilarinho da Furna.

In the early 70 s of the 20th century, the valley where this village lay became the bed of a hydro-electric dam water reservoir built in that place.

The whole process was developed with minimum precautions to protect the memory and patrimony of the spot, and the main survey and cataloguing procedures were made by HICA—"Hidroeléctrica do Cávado", later merged into the EDP—"Electricidade de Portugal" group.

It was a very quick process, and from the announcement of the works until the effective filling up of the reservoir, the local inhabitants had about one year to dismantle what they could and to move their belongings to other places.

The same happened with some documentarists and researchers who had the same period of time to capture, gather and register 1900 years of the village's history.

In 1972, after the filling up and grand opening of the reservoir, the village became a collection of submerged granite remains, and only three possible ways are now at our disposal to visit this place:

The first is diving, the second is waiting for a severe drought year, and for the consequent lowering of the dam's level sufficient to cause the emersion of the buildings and the third is to make use of the few memory records that have survived until the present day—statements, objects, publications, letters, illustrations, pictures, films and institutional documents are some of these records.

3 DATA COLLECTION

The research for available information concerning the village provided us thirty four documents or sets of documents.

Among those we mention a military map from 1950, a cadastral map, two aerial photos from a 1965 flight, a topographic survey in CAD format, a monograph entitled "Vilarinho da Furna: A Memória" (Calado 1999), to sets of images captured in different places of the village, two documentaries about the village last days, and two pieces of aerial filming taken from a helicopter by António Campos, director of one of the documentaries (Vilarinho das Furnas 1971).

In addition, some other documents, such as a 1990 military map, a 1987 chorographical map, a Google Maps land modeling, and also several YouTube documentaries and videos were gathered.

4 DATA PROCESSING

After a first phase of seriation, organization and selection of the gathered documents, we established an action strategy summarized as follows:

1. PREPARATION including:
   - DIGITIZATION of documents
   - ASSEMBLAGE of partitioned documents
   - HOMOGENIZATION of contents
2. THREE DIMENSIONAL MODELING of:
   - LAND including:
     - Digital Elevation Model (DEM)
     - LOCATION of the buildings
   - BUILDINGS consisting of:
     - SHAPE
     - FACADE
     - ROOFING
   - TEXTURES
3. FINISHING considering demands for:
   - INTEGRATION of the modeled elements
   - CHECK-UP of the results
   - CORRECTION of the detected errors

4.1 *Preparation of documents*

Most of the gathered documents was in paper, so it was necessary to digitize them all. As some documents were divided in several sheets of paper, it was necessary to scan the sheets that constituted each document, and then to assemble all the sheets, merging them in one file, with a few digital corrections.

We edited the CAD drawings, first merging some files, and then cleaning and customizing them.

In the case of cartography, grid detection and identification of cartographic coordinates were carried out.

4.2 *Three dimensional modeling*

4.2.1 *Land*

4.2.1.1 Digital elevation model

The existence of a CAD file containing a three-dimensional survey of the terrain would automatically solve the problem of land modeling, if it were not for the fact that this was a chronologically recent document, which didn't include the submerged area.

To obtain this information, we had to use other document, the 1950 Military Map.

After having imported the document of the submerged area to AutoCAD, in raster format, the respective contours were traced directly over the map. When both models were merged, some discrepancies of the contour corresponding to the maximum level of the reservoir outlines were detected.

Because of that, it was necessary to correct them, using the information taken from schematic drawings found at (Melo & Gomes, 1992) and also some video pieces taken from the documentary (Vilarinho das Furnas Aqui havia uma aldeia, s.d.).

National reference coordinate system Hayford-Gauss Lisbon was adopted, making the migration of elements between software applications much easier.

Google Sketchup (www.sketchup.com) software was chosen to make the triangulation and creation of the 3D surfaces, but it proved not to be able to process the data due to the large size of the data, what forced us to reduce the area of analysis from 80 km^2 to 25 km^2, and later to 2.16 km^2.

4.2.1.2 Location

The drawing showing the location of the buildings was made with AutoCAD directly over the cadastral map provided by EDP. Delmira Calado's ground floor plan was also imported and used as a reference element in AutoCad, for checking the other data.

It is important to notice that multiple sources of data are important to enable us to improve the precision of the obtained results.

4.2.2 *Buildings*

4.2.2.1 Form

Starting in with the drawing of the buildings implantation, the next step was to make their extrusion.

It was a uniform extrusion, made with very high values, with the purpose of later managing to cross-check the generated solids with the land surface and roofing drawings. In this way, we aimed at obtaining the most precise possible set of heights (Fig. 1).

Some buildings modeling based on photos was also done using manual, semi-automatic and automatic photogrammetric procedures.

Manual processing was done with Sketchup Photo Match tool. This tool allows quite detailed modeling of the information contained in the image through the graphical edition of some parameters,

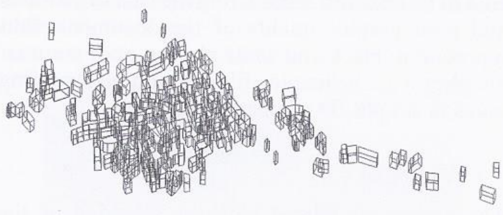

Figure 1. Block extrusion of the buildings contour polygons.

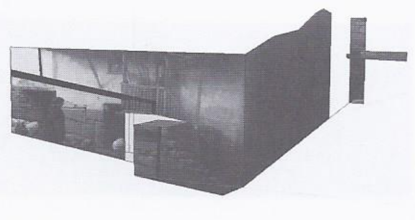

Figure 2. Example of a building modelled with Photo Match with direct application of textures to the facades.

such as the horizon location, the distance between vanishing points and, later, the introduction of a reference measurement.

Photo Match also enables to model one object based in several images taken from different viewpoints and the modeled object can then be enriched with photo textures from the images (Fig. 2).

Concerning automatic modeling, early in the process we considered testing the use of some freeware 3D reconstruction software available online; Photosynth (http://photosynth.net/) and VisualSFM (http://www.cs.washington.edu/homes/ccwu/vsfm/).

This kind of application relies on having multiple redundant images taken with small base distances, i.e., the observer must always be moving. This approach is known as structure-from-motion (SFM) (Snavely 2008). Images can be taken as single images or can be sampled frames from video sequences. First, relevant features on the digital images are automatically detected and images are correlated. Then, cameras relative orientation is determined and dense 3D point cloud is obtained.

Unfortunately, for many of the image sets, this approach did not provide good results because there was lack of camera translation movement (the several takes available in the footage had been filmed standing still and just panning the camera). Of course, the only exceptions were the sequences captured by travelling camera techniques that, together with other experiments made, allowed us to confirm the good relation between this shooting technique and automatic modeling, clearly indicating the direction we should follow in future data inquiries.

Another possibility combines some of the previous procedures with manual modeling. The followed semi-automatic approach can directly use video sequences to estimate camera poses framing the scene to be manually modeled. One solution for this approach is VideoTrace (http://punchcard.com.au/).

After camera positions are estimated, the modeling is made manually by drawing directly over the video frames. The shapes instanced in one frame are automatically tracked to the following ones allowing modeling refinement. Scale is recovered by assigning known dimensions to modeled shapes (Fig. 3).

Using the two helicopter sequences, it was possible to obtain roofing and facade models, but the poor quality of the images, the narrow capture angle and the constraints raised by these two factors did not allow us to widely use this technique for all the buildings. Nevertheless, in the cases where it was possible, a visual comparison with the previously modeled objects could be carried out in order to assess the quality of the models.

4.2.2.2 Facade

One of the simplest techniques for facade modeling, taking as reference the polygonal drawing of the plan, and already used by Domingues (Domingues & Bandeira, 2008) when modeling the city of Braga as it was in the 18th century, begins by importing the drawing or rectified photos to the CAD environment. After that, it is necessary to place it vertically in line with the edge of the facade we want to draw. After having scaled the image to equal the edge size, information about its dimension and form in the vertical direction is made available, from spans to heights, and ready to be drawn.

In this case, we used Delmira Calado's (Calado, 1999) street elevations and, much more than the position and design of the spans, our concern in this process was to obtain the heights of the buildings shown in the drawings.

After having accomplished this procedure, we managed to obtain a good characterization of the facades and accurate information about its dimensions as it is shown in figure 4.

With this technique, besides being possible to get information about heights, it is also possible and at the same time, to apply the final texture/material to the modeled facade.

4.2.2.3 Roofing

Having partially solved the height issue, it was understood that the information contained in the survey drawings would not be enough to complete the trilogy "form—facade—roofing" that embodies the complete 3D modeling of a building because, to conclude this trilogy, roofing was still missing.

Modeling the roofs was done using the photogrammetric application Photomodeler (www.photomodeler.com/).

The pair of aerial photos we had, contained some information associated regarding de the camera, namely its focal length and fiducial marks. By selecting a set of fourteen homologous points in both photos (theoretically five are enough) relative orientation of the cameras was done. After relative orientation, modeling follows the triangulation principle (Mikhail, 2001). The operator picks pairs of homologous points in both images in order to recover the shape of the elements to be modeled.

External orientation of the final model was done by assigning known world coordinates to the model. Although three pairs of homologous points is enough to calculate the parameters of this transformation, in practice if we use more points, a more robust solution is found.

Through this technique, a quite complete model of the village roofing was obtained, as it can be observed in the anaglyph done with the stereographic visualization option in Photomodeler (Fig. 5).

4.2.3 *Textures*

The elements of texture intended for application to the land model, being scarce in the submerged area, limited to the two air photographs, are in the other hand abundant in the area above the maximum level of the reservoir, with several images available.

As all the information that was used for modeling above the reservoir maximum level is recent, it was decided to make a combination of both realities, being the submerged area graphically represented by one of the 1965 air photos, and the emerged area by texture mapping of air photos obtained with the Bing Maps (www.bing.com/maps/) application.

The mapping of textures to the buildings resulted essentially from the process already described.

Applying texture to the roofing was not considered to be relevant, considering the lack of richness and poor graphic quality of the documents that represent it; black and white photos, poor contrast air photos or helicopter filming and also roofing plans in simple 2D geometric drawings.

4.3 *Finishing*

The operations related with the finishing of the data treatment, including integration, check-up and correction of results were made in two phases.

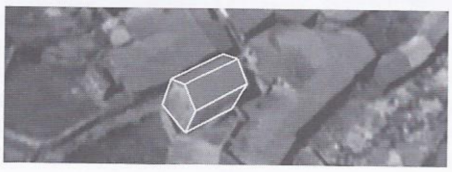

Figure 3. Example of a building modeled with VideoTrace.

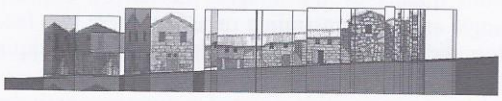

Figure 4. Flank of a street with elevation drawings applied as materials to building blocks.

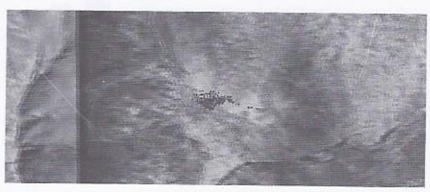

Figure 5. Roofs anaglyph generated with Photomodeler.

This procedure of information cross-checking, many times overlapping and/or redundant, allowed us to achieve the partial modeling objectives that contributed to the final objective of a three-dimensional model of the village.

The fulfilment of this final objective corresponded to the second finishing phase where, with the use of geographic coordinates common to all the elements, it was possible to integrate, to check and to refine the results of the first phase and then, to obtain a quite truthful georeferenced three-dimensional model of the village before being submerged. The software used for the final model assembly was Google Sketchup. The first assembly made in this phase was based on the DEM, cross-checking it with the set of extruded blocks of buildings. This procedure made possible the creation of a new drawing with building polygons, adapted to the terrain morphology (Fig. 6).

These intersection polygons were used to support the facades modeling based on the buildings elevation drawings, since these are the lines that identify the starting point of the building walls.

As only a small part of the heights was directly found through the information supplied by Delmira Calado's elevation drawings, it was necessary to use the set of roofing models obtained with Photomodeler, in order that, when cross-checking it with the raw blocks of the buildings, it would be possible to find the rest of them (Fig. 7).

Aiming at model simplification, a second roofing set was made based on Delmira Calado's roofing plan, which ended by being used in the final model. As it was drawn in 2D, only by cross-checking it with the set obtained with Photomodeler was it possible to get information about roof eaves and ridges. In figure 8 both roof models can be observed.

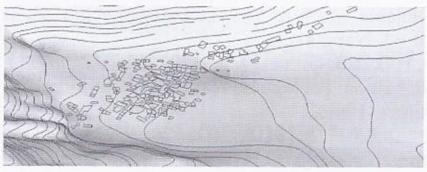

Figure 6. Intersection polygons.

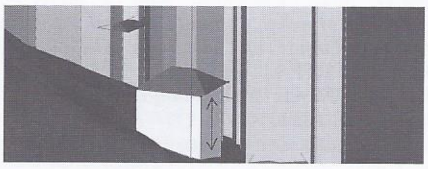

Figure 7. Adaptation of a building's raw block level to its roofing altimetric positioning.

Considering the level of detail of data available, it was not relevant to consider the irregularities that old buildings usually have. So, in order to control the modeling process, particularly regarding the roofs, some geometrical constraints were imposed, such as to consider that the roofs surfaces were approximately plan and that roof eaves were approximately horizontal. These were made manually, taking the photographic images and cinematographic sequences as a reference in most part of the cases.

As the blocks of buildings + roofing were already consolidated, a final process of heights verification was started, in attempt to diminish the error margins of its modeling.

For that purpose we used the Sketchup tool Photo Match, where overall photos and panoramic images resulting from a composition previously accomplished with Microsoft ICE (http://research.microsoft.com/en-us/um/redmond/groups/ivm/ice/), overlapped the model (Fig. 9).

This procedure allowed the correction of some heights that happened to be clearly oversized, thus completing the building modeling purely based on direct information. As there is no information concerning the textures of facades of many of the buildings, and in view of the final graphical homogenization, it was created a new material with Sketchup to which an adapted image excerpt of one of Delmira Calado's elevation drawings was conferred. This new material was later applied to the buildings without texture, resulting in a final set with a more homogeneous design as it can be observed in figure 10.

The completion of the model was reached with small one-off corrections made by direct observa-

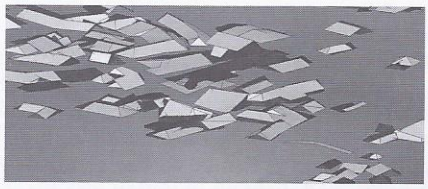

Figure 8. Overlapping of the two sets of roofing models.

Figure 9. Overlapping of photographs to the model using Photo Match for correction of heights.

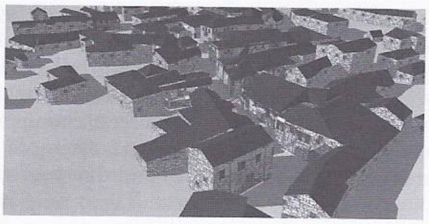

Figure 10. General view of the village model.

tion of all the available photograph, filming and drawing elements, and subsequent production of images and videos for the final presentation (davifonso, 2012).

5 CONCLUSIONS

Drawing, painting, sculpture, engraving, photographing, filming, have always been Man's forms of expression and, at the same time, forms that Man has had to understand his past and his History.

Formerly, they were just mere deposits of memory, available only to be consulted and interpreted.

Nevertheless, today we are able to interact in a different way with those sources and to generate new information from them.

In this paper we described a methodology to integrate multiple sources of data regarding an ex-place, and with that data we were able to recover a three-dimensional model. The produced model is itself a source of information and interpretation. In this particular example, it allow us to revive the submerged village of *Vilarinho da Furna*, and it can be used as a support of inquiry and understanding.

Trying to assess the model fidelity to the original village environment, when it was inhabited, a set of images of the model were produced (reproducing possible point of views of a person walking). The images were then presented to one of the original inhabitants, and a simple question was made: do you identify your village from each of this images? The response was positive to the majority of them, and two of them were even identified as "very similar".

The descriptive style of this paper is intentional, since we have the ambition that it can be used as guidance for others who want to develop a similar work. This is particularly relevant since it is known that there are innumerable lost and unexploited ex-places in the world that could benefit from this kind of work. Although it is true that each case is a different one, i.e., it is not expected that, for a similar situation, a collection of documents like the one gathered within the scope of this study exists, we believe that the lessons learnt with this experience, with due adjustments, can be adapted to establish proper strategies in other situations of the same type.

It is true that technical capacities, namely at software level, are constantly evolving. And for that reason, different, and useful techniques may be available in the future. That may change the workflows. But in the principles level, what was considered in this work will remain valid. Documentary sources, technical solutions, procedures and workflows have to be revealed and made available. This is the only way the produced materials can be judged as valid and reliable, and results can be verified and replicated. Heritage documentation is not compatible with "black boxes", as it is expressed in the London Charter. With this work a path has been traced, and it is hoped that, with this paper, this path has been clarified and "mapped" in a way that can be followed by future researchers to bring ex-places "back to life", metaphorically speaking, allowing everyone to enjoy them again.

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