

FINDING A SUITABLE MODEL FOR ARCHAEOLOGISTS. APPLICATION TO THE DOCUMENTATION OF A COMPOUND WALL OF RIBEAUVILLÉ (ALSACE)

Tania LANDES¹, Jean-Jacques SCHWIEN², Solveig BERGER¹, Nicolas PETER¹, Emmanuel ALBY¹
and Pierre GRUSSENMEYER¹

¹The Image Sciences, Computer Sciences and Remote Sensing Laboratory (LSIIT),
INSA Strasbourg, France

(tania.landes, solveig.berger, nicolas.peter, emmanuel.alby, pierre.grussenmeyer)@insa-
strasbourg.fr

²Equipe Archéologie de la Meuse au Rhin (AMeR), Strasbourg University, France
schwien.jean-jacques@wanadoo.fr

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Abstract:

Archaeologists need surveyors and surveyors need archaeologists! Even more archaeologists show interest for new measurement approaches and technologies, although they tend to quickly return to their traditional well known techniques. On the other side, the surveyor produces very impressive 2D or 3D models, which unfortunately, remain in stand-by on its computer. The main difficulty is the mutual understanding between two experts in different fields, in order to find the most appropriate model regarding the specifications. This paper will present three different products which have been proposed to archaeologists for helping them to record a compound wall in an accurate and efficient way. The compound wall is located in Ribeauvillé, Alsace (France). The first deliverable is a 2D map composed of series of orthophotos covering an important part of the wall. The second type of product is a dense point cloud acquired by 3D laser scanning techniques. The third deliverable is a textured 3D model based on the previous processed point cloud on which radiometric equalized photographs have been projected. The advantages and drawbacks of each product have been discussed with archaeologists. Interesting issues about the most appropriate solution are presented. The most appropriate is not necessarily the faster or the most expensive, but the model that will actually be exploited by the archaeologists.

1. INTRODUCTION

Since several years, the team AMeR from Strasbourg University works on the understanding of the defensive system development of the medieval city Ribeauvillé dated from the XIIIth and the XVIIth century. Requirements and objective of archaeologists are generally the production of stratigraphic diagrams. The method usually used to produce a graphic product is a survey of every stone (stone-by-stone surveying process). Simultaneously, the object under study is analysed to define the relative chronology elements, e.g. in which chronology the stones composing a wall have been placed.

The approach of specific architectural and archaeological entities requires a detailed geometric recording. Also the possibility to simulate missing elements using cartographic and old iconographic sources is desired by the archaeologists. A close collaboration between archaeologists and surveyors became obvious. In this context, the “Photogrammetry and Geomatic Group” of INSA de Strasbourg has been involved in the project.

The main difficulty is less to find the acquisition and processing techniques to implement than the definition of the most appropriate and useful model that meets the requirements of the archaeologists. Aim of this paper is to show, in support of a real study case, the products which a surveyor is able to provide and the interactions with archaeologists for adapting them to their specific requirements.

2. RELATED WORKS

A huge number of projects dealing with 3D modelling and recording of cultural heritage monuments or remains have been published in the last decade (see the numerous papers published in CIPA and 3D-ARCH proceedings). They can for instance be categorized regarding the technique they used. Currently, photogrammetry and laser scanning are the most widely encountered techniques, although traditional survey techniques remain necessary for georeferencing the final products [1,2,3,4]. When a 3D product is needed, a lot of questions must be answered: what kind of data exist (maps, photographs, drawings)? What is the required level of detail? What about the precision of the final model? What use will be made of this model? What knowledge does the user have in managing 3D data? What knowledge does the producer need to construct the right model? To be shared and managed, the models need to be handled in databases. Therefore the questions of data integration, publishing and sharing must also be considered in the future.

Although a detailed 3D model contains all information allowing to produce specific sections (horizontal, vertical or not conventional sections) and therefore all usual maps, it is often subsampled or reduced to a 2D drawing due to a lack of software or knowledge in properly handling 3D data by non-experts [5]. Therefore a big effort must be made in the interdisciplinary task of cultural heritage recording, in order to avoid this regress and to be able to communicate the wide potential of a 3D model, under the condition that it respects the requirements of the user [6]. In this study, the target users are archaeologists.

3. CASE STUDY: COMPOUND WALL OF RIBEAUVILLE

3.1 Description of the wall

The archaeological entity under study is a segment of curtain located in Ribeauvillé which is preserved on about one hundred meters.

Ribeauvillé is a medieval city located in Alsace (France). It was founded in the thirteenth century and has numerous elements composing the defense system, on which the AMeR team is working.

The town council of Ribeauvillé noticed that one of the compound walls of the city presents collapsing risks, and decided to consolidate it with modern materials, as soon as possible. But the masons' interventions could destroy essential information of the wall structure and its construction steps, which are precious for the archaeologists. So the recording of the wall is urgent. A footpath is going along the north side of the wall. The south side overlooks a park. Several battlements are preserved and many traces of a parapet corbelled are present on the south side. A well preserved tower is located in the lower part of the wall (Figure 1).



Figure 1: Photograph of the upper part (left) and lower part (right) of the compound wall

3.2 Specifications of archaeologists

The study of a defensive system component is multi-purpose. It aims:

- to identify and characterize the architectural entities (doors, towers, curtain walls, scarps, breaches, counterscarp, ditch, etc.);
- to recognize if possible, the stratigraphic elevations and relative chronology of the works;

- to reconstruct the steps of topo-chronological development of the defensive system, by replacing each phase in its geographic, political, military, economic and social context;
- to analyse the relationship between the defensive system and the urban landscape (water system, road network, religious institutions, schools and public facilities, etc.) and their respective evolutions.

Usually, the technique used by archaeologists to make their detailed survey is to draw by hand the objects supported by basic measurement techniques (thread, plumb bob, measuring tape). So the graphic result they produce is a survey of the wall by considering every stone individually. Also the use of photographs is a common solution but usually they are used without accurate rectification.

The advantage for archaeologists to consider collaboration with surveyors is not only to prepare the survey of the area, but also to make use of new measurement technologies and 3D products, which allow to rationalize and speed up the acquisition process, without loss of accuracy.

Surveyors are experts of measure. They work in fields like geodesy, remote sensing, photogrammetry, tachometry, etc. They produce maps at every scale, with numerous techniques and methods. Since the beginning, they are used to work in 3D spaces. Close cooperation through rewarding dialogues might help surveyors to give more sense to the 3D products they produce. On the other hand, it might facilitate the work of archaeologists and help them documenting, visualizing and archiving the object under study. This requires that the dialogue is set up and that the terminology is consistent between the two worlds.

3.3 Available data

A 2D topographic map of the wall outlines and the surrounding area is available. It has been produced by a professional surveyor as part of a development project of the adjacent park. However, a new network of traverse points has been created around the wall, since the existing points were not sufficient and not adequately placed regarding the scheduled surveys on the wall.

Digital photographs with high overlapping rate have been taken with a Canon EOS 5 D with 28 mm and 85 mm focal lengths (4368 x 2912 pixels), inspired by the “3x3 Rules for Simple Photogrammetric Documentation of Architecture” protocol, as suggested by CIPA Heritage Documentation. Using the previously created stations, some characteristic points on the surface of the wall have been acquired by tachometric measurements in order to have control points available on the wall.

At last, several point clouds have been acquired by laser scanning measurements along one side of the wall. The system used was a Trimble GX scanner. Again, the topographic network was useful, since this scanner allows direct georeferencing of point clouds. The spatial resolution has been set to 1 cm at 50 m, i.e. about 1 point every 2 mm at the surface of the wall. This high resolution was required to record the mortar joints between the blocks.

In this first exploration step, only one side of the 108 m long wall has been considered. When the most adequate solution among the proposed products is defined, the methodology will be extended to the entire wall.

4. PROPOSED PRODUCTS

Three different products have been proposed to the archaeologists for helping them to record the wall in a more accurate and efficient way. The first deliverable is a 2D digital map composed of series of orthophotos covering an important part of the wall. The second type of product is a dense point cloud acquired by terrestrial laser scanning . The third deliverable is a textured 3D model based on the previous processed point clouds on which radiometric equalized photographs have been projected.

4.1 Two dimensional model composed of orthophotos

Orthophotos have been produced by using Photomodeler software. With the 28 mm focal length, photos have been taken at 5m from the wall, so a pixel on the photo sizes about 1 mm in object space. With the 85 mm focal length, photos have been taken at approximately 7 m from the wall, so a pixel on the photo sizes about 2 mm.

The residuals were lower than the tolerance, fixed at 1 cm for both focal lengths. If residuals are over the fixed tolerance, homologous points must be replaced on every photo until the residuals achieve an acceptable value.

Advantage of orthophotos for archaeologists is that they can use them to directly digitize the stone outlines at a right scale and simultaneously handle radiometric information. However, the depth of the object cannot be measured, neither the volume. This is the main drawback of this kind of 2D product. Figure 2 shows an orthophoto derived from three overlapping photographs on a portion of the wall.

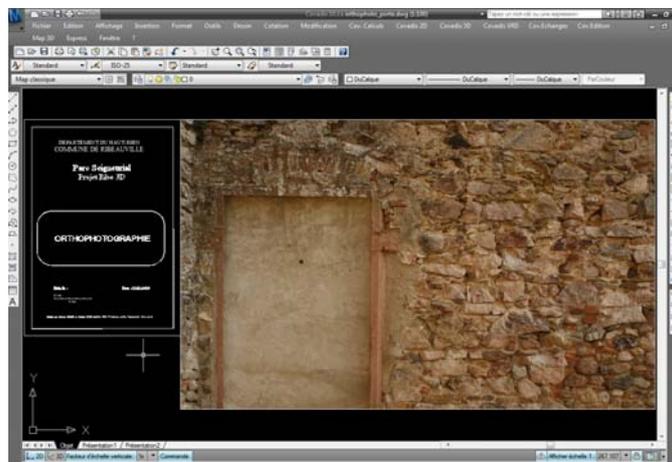


Figure 2: Presentation in AutoCAD (Autodesk) of an orthophoto (6000 x 6000 pixels) covering a portion of the wall.

The integration of orthorectified images in the AutoCAD environment facilitates the transmission of files between engineers and archaeologists, since this software is commonly used in both communities. Figure 3 shows a succession of orthophotos jointed together into a mosaic.



Figure 3: Mosaic of orthophotos covering the upper part of the compound wall (printed at scale 1/80 for the archaeologists).

This solution has been limited to the upper part of the wall and can be generalized to the entire wall if it is chosen as best adapted product.

4.2 Three dimensional dense point cloud

Terrestrial laser scanner recordings have been done on one side of the wall. The Trimble GX laser scanner (Trimble) used in this study has captured about 36 million of points along the footpath. The other side of the wall will be acquired as soon as the vegetation will be pruned. The scanner under study can enter into a traverse, like surveyors do it with a tachometer. So, a direct georeferencing of the point clouds has been performed. The network of traverse points set up on site was useful for centring the scanner or targets on known points. The main advantage of working in direct georeferencing is that every point cloud is directly placed into the reference coordinate system. This allows not only to replace the result easily and accurately on a cadastral map, but also to locate, immediately after the scan, eventual lacks in the point cloud and to react in situ. In this case no further geometric process (registration) is necessary. Figure 4 presents subset of the raw point cloud at the upper part of the wall. In this form, the raw point cloud already constitutes a product of its own. Since it is georeferenced, it can be superimposed to existing maps. It is possible to make measurements of distances or angles, create sections, profiles, digital surface models, etc. This assumes, however, to have a data exchange format that is adapted for both archaeologists and surveyors.

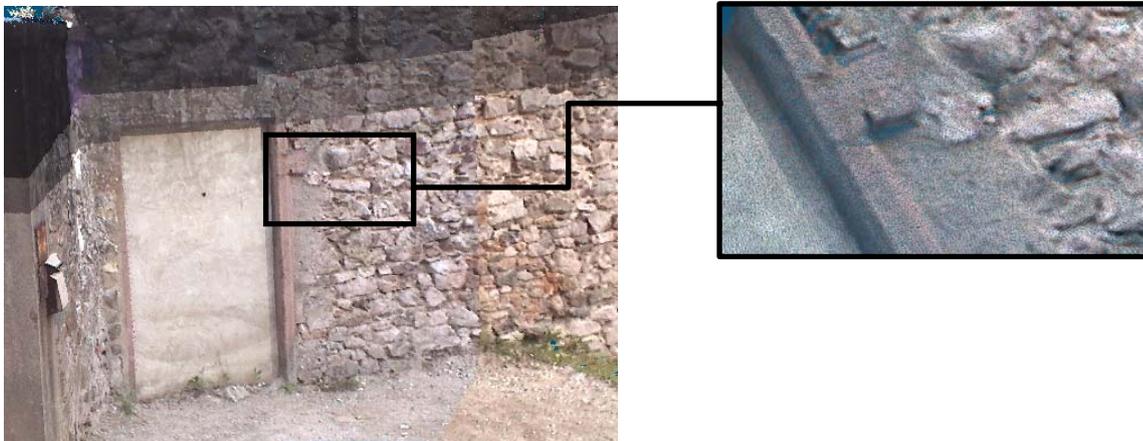


Figure 4: “True colour” point cloud, obtained by assigning RGB information from the video of the scanner to the measured points

4.3 Three dimensional textured meshed model

Based on the previous point cloud, instead of working with individual points in a point cloud, a meshed model can be produced. The meshed model provides a surface to the captured object. For this purpose, the points are generally connected by a Delaunay triangulation after filtering of data. Based on this surface, a texture can be affected to the model in order to make it more realistic. The textured model is generally obtained by affecting a pattern or photographs on the modelled surface. For example, with photographs of geometric and radiometric quality, it is possible to project them on the surface model to assign a more realistic texture (Figure 5).

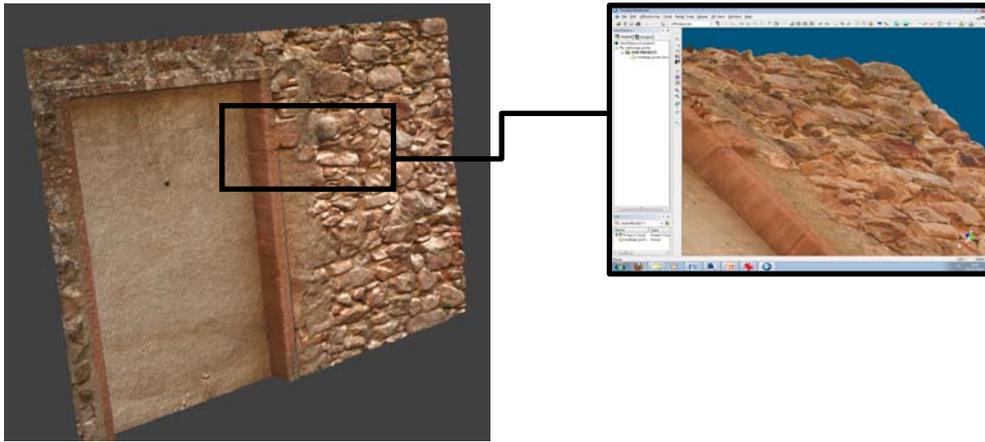


Figure 5: 3D meshed and textured model obtained on the upper part of the compound wall

This solution presents the advantage to provide a photo-realistic result of the wall. However, the surface texturing method requires a previously meshed model. As soon as a mesh must be produced, some simplifications and smoothing through filtering are inevitable. This represents a drawback for archaeologists, because the filtering operation deteriorates the raw model. Moreover, the manual processing time induced for texturing is also important.

The transmission of this data type was attempted via the 3D interchange format PDF (Adobe Acrobat 3D), which is widespread since the Acrobat Reader is free software.

5. DISCUSSION

The advantages and drawbacks of each product have been discussed with archaeologists and historians. Interesting issues about the most appropriate solution did arise.

Concerning the quality of the final product, the mosaic of orthophotos is surely the most accurate in this study. A final precision of ± 1 to 2 cm in the center of each orthophoto and ± 5 cm near the junction lines has been reached (in 2D).

Individual or composed orthophotos are adapted for primary documentation (for memory). It gives the state of the wall at a specific date. If necessary, based on these scaled maps, a stone-by-stone restitution is possible.

Three dimensional models obtained by laserscanning techniques have firstly enthusiastically been welcomed. Undeniable advantage of techniques leading to a 3D model is the possibility to view the object in 3D space by turning around it. It allows very original point of views. Even if every kind of map, section, profile can be extracted from a 3D model (as point cloud, or meshed), after longer discussions, it became clear, that the software for processing them is missing in archaeological research labs.

Therefore, the most appropriate model is not necessarily the faster or the less expensive, but the model that will actually be exploited by archaeologists.

The time factor for producing the model is not the most important criterion, at least for the post-processing steps. However, the time taken for the acquisition must be considered. Archaeologists must often work in a short delay, i.e. directly after scaffolding installation and before masons begin to fasten the stones. If the laserscanning technique is chosen, scaffoldings represent obstacles in the point cloud acquisition. So the scanning must take place before, that means unfortunately that vegetated areas will not be removed (ivy is spreading on the wall). Figure 6 shows the meshed and textured model obtained for the lower part of the wall, where ivy bushes remains on the top of the wall.

Since the processing steps leading to the three solutions have been established, further experiments will be performed to quantify the time spent for achieving every solution from the acquisition until the final product.



Figure 6: 3D meshed and textured model obtained on the lower part of the compound wall, covered with vegetation

Obviously the question of costs, particularly sensitive in the archaeological field, must be taken into account. Today, with commercial cameras, digital photographs can be produced by everyone within a limited budget. It is not comparable to the costs occurred by a laserscanner, with its associated software and adequate hardware. The calculation of orthophotos does not need very expensive software or hardware. Nevertheless they remain in 2D, so the volumetric information is lost.

Finally, it has been decided in the case of the compound wall, to realise orthophotos for the straight portions of the wall and to produce a 3D model of the tower, which geometry is less trivial. A projection of the tower onto a 2D map has also been mentioned. It means that the archaeologists involved in this project are not convinced of the necessity to produce 3D models for every purpose.

6. CONCLUSION AND FUTURE WORK

Three types of products have been proposed to archaeologists to address the issue of the topographic survey of the medieval wall of Ribeauvillé. The first, suggesting the processing of orthophotos, has the advantage of allowing to print 2D photographs at a given scale. These maps in digital or paper form are familiar for archaeologists. They are useful not only to feed the database of archives on the wall, but mainly to facilitate subsequent interpretation and /or stone-by-stone digitizing. The second solution, suggesting the use of a laser scanner has the advantage of providing a three-dimensional point clouds or surface model of the wall, with all the deliverables to be derived from (sections at different levels, profiles, direct measurements, simulations, etc.). But this solution has the disadvantage of requiring specific software and consequent hardware. Obviously, the choice for a common exchange format between project partners is essential, but also software allowing the analysis of the model by the final user is necessary.

In a future work, an intermediate solution will be considered which should bring all the advantages of the products obtained with laser scanning, without the drawbacks of costs. It consists in using photographs with high overlapping rate and producing dense point clouds through dense matching methods [7]. A supplementary advantage of this technique is that it also allows, within some conditions, the processing of old archive photographs.

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