

FROM 3D RECORDING TO VIRTUAL VISIT OF ARCHEAOLOGICAL SITES: METHODOLOGY APPLIED TO THE MEDIEVAL FORTRESS OF CHATEL SUR MOSELLE (FRANCE)

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Abstract:

We consider in this paper dedicated to 3D documentation in archaeology two target audiences: firstly the archaeologist who needs data for his study and research and secondly the visitor who can discover the site in different ways from several points of view. The processing of data based representations takes different forms according to these recipients. On the one hand, the scientific standpoint is the engine for obtaining media on which assumptions of archaeological restoration are based. On the other side, the achievement of realistic and didactic models is motivated by the valorization of the site. Those models describe the characteristics and define the heritage value of the site. But the purpose of the different representations and the multiple study areas does not require the same level of detail and accuracy. The project discussed in the paper is the medieval fortress of Châtel-sur-Moselle (France) where several transformations have undergone since the 13th Century. This site covers a large area and includes several underground constructions. Digitization by photogrammetry and lasergrammetry of such a site requires different means and methods to achieve satisfactory models for both recipients. Airborne helicopter LiDAR surveys have been used to survey the outer parts of the site and surroundings. A combination of terrestrial techniques (geodesy, TLS, photogrammetry) were used to record the interior parts. Several measurement campaigns were motivated to obtain effective representations for the archaeologist and the visitor. It is important to have an overview on both the outdoor and indoor areas to understand the configuration of the site but also for interpreting some features and compare them with other elements. Three types of 3D models have been used to deliver a representation according to the needs of the archaeologist and the visitor. An overall model of the outside helps in the positioning of existing remains. A simplified indoor model follows and shows the distribution and complexity of the galleries. Finally the third level of detail gives the possibility in some areas to study details of masonry bonds to facilitate the interpretation of different periods. The multiple models and heterogeneous documents on the fortress is part of the data management issue to facilitate consultation, organization and updating of the documentation.

1. INTRODUCTION

In the field of documentation of cultural heritage, an unprecedented perception of complex spaces is allowed by three-dimensional data. Lasergrammetry and photogrammetry are used to obtain 3D measurements without contact on an object with a precision controlled. It is possible to directly create coherence between spaces. These techniques enable us to reconstruct the geometry of objects of interest. The resulting models can be used to manage representations or, after treatment, can pretend to be a medium for communication. In this paper, technics used and methods to produce different 3D model will be presented. An application to the medieval fortress of Châtel-sur-Moselle (France) let us illustrate an appropriate way to differentiate 3D model for scientific use and for communicate to a large audience.

1. TECHNICS

The three major principles embedded in scanners are the time of flight, triangulation and the phase shift. The differences of performances are not negligible. The choice of appropriate device is very significant; performances are variable and dependent of these differences. The TLS is essential for dense scanning of the fortress. To achieve these measures, we used the terrestrial laser scanner of the group. This device is a Trimble GX, which uses the time of flight as measuring technique. This system is dedicated to the measure of outdoor elements, because it does not have a panoramic field of view. This device is not well suited for this kind of survey. It still allows direct Geo-Referencing of data as shown in [1]. It is a great help to manage point cloud despite the occurrence of large holes. The direct Geo-Referencing allows not to perform any stations registration; the final point cloud corresponds to the import of all stations in a single file without additional treatment. A second technics was used to complement the data when space configuration required it.

Although based on very old principles, photogrammetry has consistently evolved to incorporate advances in technology. In this way, digital photogrammetry has taken advantage of digital cameras and computer tools to enable automation of its principles. The laser scanner is fundamentally efficient. The rapid acquisition of points makes it an ideal tool. But recently it is possible to create large point clouds with a stereo pair. This process has been developed in [2]. The dense stereo matching can compete laser scanning at the level of data quality but also in terms of cost.

The geometric documentation allows representing a space, as it is constituted. The dimensional analogy makes it possible. When geometric documentation is not necessary, it is thinkable to restore, only with images of the space, the scene as observed from a specific location. The spherical panorama is an interesting tool to give the visitor an overview on the space at lower cost. Several dozen of images taken from the same point of view give the possibility to interactively visualize a space. For an overview of quality it must comply with minimum requirements. A wide-angle lens, a panoramic head and a tripod is a minimum to achieve.

2. DIGITIZING

The fortress of "chatel-sur-Moselle" is an imposing fortified complex, composed of a large number of interior spaces. Before beginning the acquisition phase, it was necessary to establish a network of control points to geo-reference all data. Each stage of acquisition (handled by TLS or Photogrammetry) can be recalculated in the same coordinate system.

2.1. Digital acquisition

The site configuration (indoor, narrow galleries, room height, etc..) and the very limited scope of acquisition ($360^\circ - 60^\circ$) are not easy and require us to vary the height of the device by multiplying stations or incline the sensor in certain parts. Beyond these performance constraints, technically we were unable to measure some parts of the fortress. To overcome this problem, we employed photogrammetry as a complementary technique.

To complement the laser scanner measures, the production technique of point cloud by photogrammetry should be used. In this project, we decided to employ this approach, through the DStM algorithm implemented in software PhotoModeler-Scanner to create point clouds by photogrammetry. For taking pictures, we used a camera Canon EOS 5D metric with three Canon calibrated lenses. Depending on the complexity of the object, several stereopairs can be made for a full acquisition. In addition to geometric information, photography provides radiometric information of the object that can be reused for texturing of the future 3D models

2.2. Merging TLS and Photogrammetry

The results of the DSM may be integrated to the laser scanner data without loss of reliability of the hybrid point cloud. This technique has been adopted mainly for the upper parts of the rooms, since even inclined; the scanner was not able to measure the vaults (observation cone 60°). The full scan took several photogrammetric projects that once merged, helped fill the holes.

2.3. Hybrid point cloud

Fifteen PhotoModeler Scanner projects have been produced and about 3 million points have been generated. Regarding the laser scanner measures, we conducted twenty stations by varying the height of the device and its inclination. With a spatial resolution of 10mm at 5m, we measured more than 13 million points. After resampling to 1cm the entire point cloud, the final hybrid point cloud is composed of 5.3 million points before modeling. As it also has been explained in [3], fusion of TLS and photogrammetric data allowed us to obtain complete data set. Figure 1 gives an overview of overall data acquired in the fortress during year 2010.

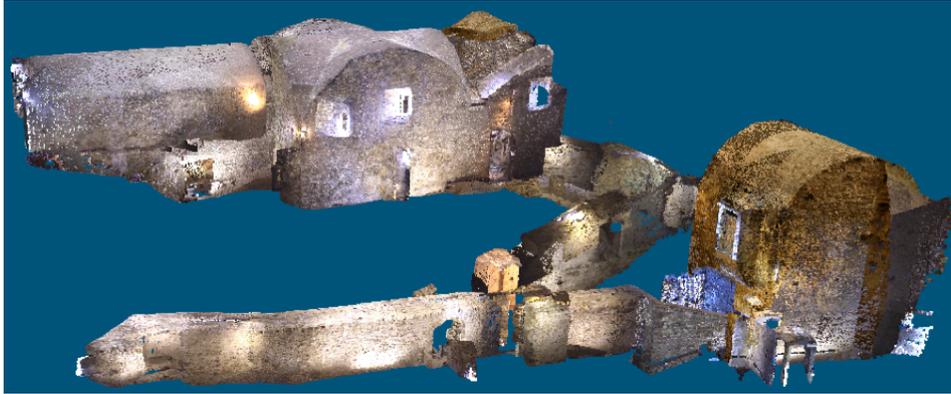


Figure 1: Data integration of merged photogrammetric and TLS data into one point cloud of inner spaces of the fortress.

3. MODELLING AND DIFUSION

This chapter presents the different modeling and texturing approaches used for the project. The extent of the site requires several modeling methods that need different procedures for texturing. At the level of the fortress, the realization of a mesh model of all spaces is not possible if one wishes to maintain a fluid interaction. To view the site as a whole, and thus keep a spatial coherence between modeled spaces, we must create a geometric and simplified model. The destination of the 3D model has not only the objective the communication on the site, but it also has a scientific ambition. We then decided to develop models with two levels of detail, a geometric model of the whole of the fortress (communication) and mesh models for some specific areas (scientific purpose). To provide reliable and useful data, as proposed in [4,5], we put a stress on data acquisition and post-processing according to spaces configurations. Finally, the project being planned over several years, it is essential to put in place a complete and effective workflow that can be reused and adapted for the remaining program.

3.1. Geometric model

The principle of a geometric model is, by definition, to simplify reality by using mathematical primitives (plane, cylinder, cone, etc..) to obtain a good visualization and fluid movements. The realization of the geometric model has several objectives. Indeed, we would like both to provide a simple representation of architectural elements in order to limit the amount of information, but on the other hand we want the model to be as close as possible to the point cloud resulting from the acquisition. In addition, visualization of the model should be aesthetically pleasing to satisfy the visitor who will give, in turn, less importance on archaeological or architectural fidelity of elements of this heritage. Finally, we aim that the model can be geometrically simple, close to reality and aesthetic since it will be released as animations, renderings and 3D models.

While the acquisition and registration of measures are treated with a high degree of automation, geometric modeling stage, is largely manual. Nevertheless, we investigated a workflow of operational treatments for the modeling of the fortress. As a first step, manual segmentation of point cloud must be realised to define the most appropriate geometric primitives. This step is crucial and must be done carefully because we have as a goal to be close to reality as shown in figure 2.

Regarding the vaults at the different stages of construction of this building, design techniques, articulation and structuring used mathematics primitives such as cylinders. Today, we find this method of mathematical

simplification of architectural elements in digital acquisitions either lasergrammetry or photogrammetry. This fortress design helps the creation of a geometric model that is both simple in geometry, aesthetic and close to reality.

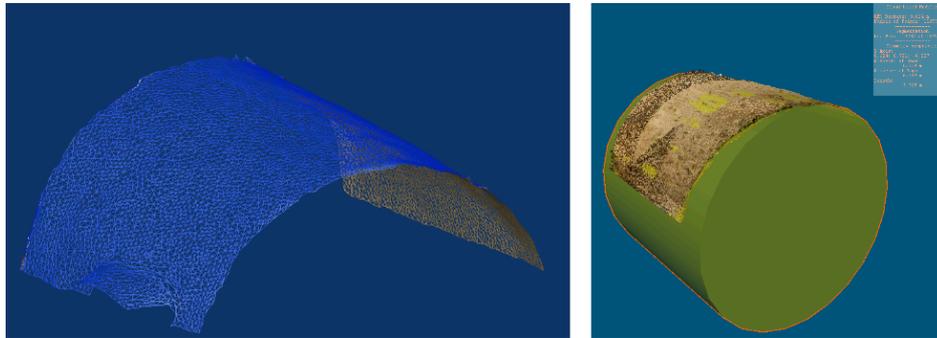


Figure 2: Definition of mathematical primitives for a vault. Right, a mesh from point cloud; left, detection of the cone closest to the mesh.

Once the segmentation and the choice of primitives made, it is necessary to carry out modeling of spaces and openings. As regards modelling of openings, the remote measurement techniques allow acquisition of comprehensive information, but they are not necessarily characteristic points of an object.

For a mesh-type surface modeling, the large amount of points is not a complication. In contrast to geometric modeling, which requires extraction of information such as 3D polylines, the amount of information makes the treatments very tough, which generates a lack of performance. To facilitate the reading of the outline of architectural details, we used algorithms of automatic search of contours found in [6]. Extraction of contours is an undeniable and effective assistance to the segmentation of a point cloud regarding to geometric modeling of such heritage. Figure 3 give an overview of edge extraction applied to a wall of the fortress. Figure 4 shows the complete and simplified Model corresponding to dataset presented in figure 1.



Figure 3: Automatic detection of contours on a window. Left: point cloud; in the middle: automatic edge detection and right the design of 3D polylines on the window.



Figure 4: 3D model resulting from simplifications

We have implemented a procedure to inspect the quality of the model based on the initial cloud of points. The principle is based on the measurement of spatial distances between each point and model. This method allows both qualitative and quantitative studies that adjust and correct modeling steps. Thus, all spaces have been rigorously analyzed to combine simplicity, reliability and aesthetics on the model. With regard to the final model, its last analysis highlights some fidelity, since we see that more than 92% of deviations are less than 5cm, and a little less than half of the measured differences are subcentimetric. Some elements were not taken into account in the model, which results in differences higher than 5cm, shown in red on figure 5. This omission of information is not a fault, but is rather a will. Indeed, some parts have no real interest in a simple "geometric" point of view of the fortress and sometimes the elements are too complex to be represented in a faithful manner. All this leads to exceptionally reduce the level of detail and can limit the amount of information to meet the goal of simplicity.

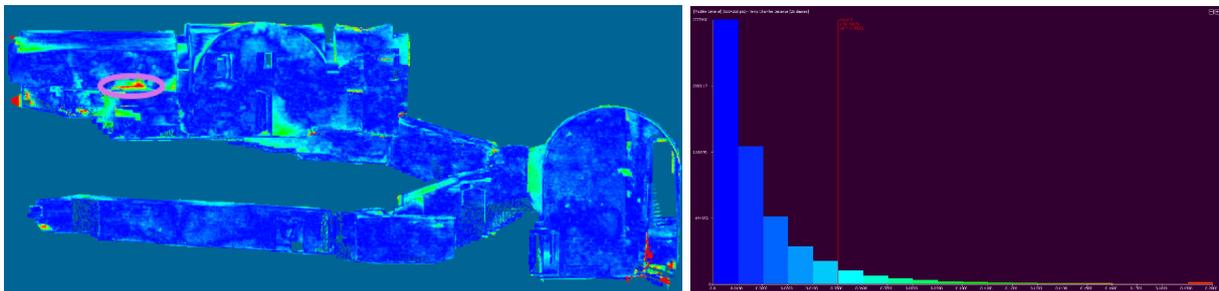


Figure 5: Qualitative and quantitative analysis of the geometric model based on the initial point cloud. On the left: spatial distribution of differences between the point cloud and the geometric model; on the right frequency histogram of differences of distances

Once the geometric model created and controlled, a final treatment on the texture is needed before its release. While our modeling approach was able to meet the objectives of simplicity and fidelity, research on the texturing respond partly for aesthetics consideration. Early research concerned the contribution of the real texture to the geometric model, but the projection of the image on the geometric model highlights certain distortions due to the geometric simplifications. These offsets are not systematic, but around the fortress several areas suffer from this situation. Once the awareness of these distortions, the geometric model loses all credibility, because even if it remains close to reality, it does not replace the mesh model that lends itself more to the true texture mapping. The solution is to use generic texture whose pattern undergoes a repetition. Desiring to preserve the radiometry of the fortress, we produced seven textures from photographs taken during acquisition campaigns. Creating a generic texture is not easy, because it must consider the concept of repeatability and joins management so that the result can be uniform. The manual work is a long and delicate, it is for this reason that we sought an automated method that can be adopted for the remaining project. Thanks for the plugin Texturize GIMP1, it is possible to automatically generate tillable textures. Using this tool we have been able to quickly and easily generate textures for walls, floors and vaults of the fortress. Finally, in terms of rendering, the results in SketchUp are acceptable insofar as this application is intended for modeling and not the creation of realistic model. The effectiveness of communication on the

site, through renderings and animations, is directly related to the quality of images from the geometric model. Figure 6 presents two rendered images for different purposes.

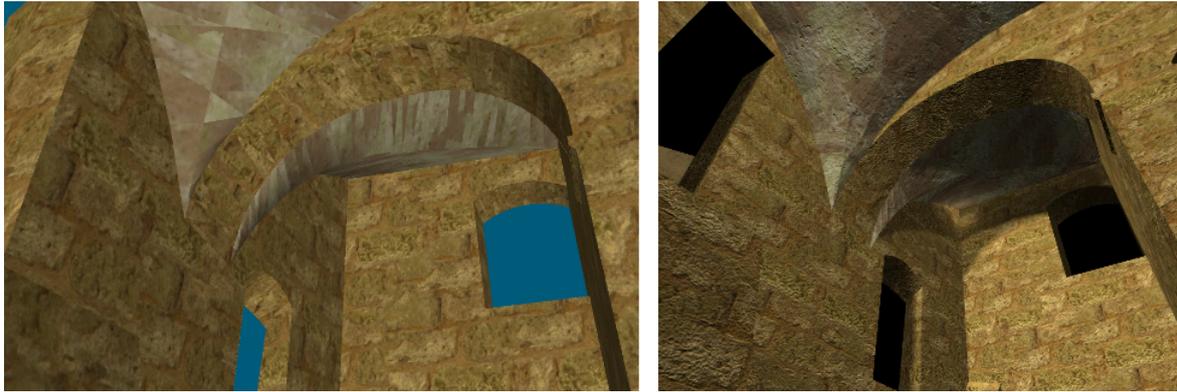


Figure 6: Comparison between simplified 3D model with generic textures (left) and the same model with finer texture and light treatments for animations (right)

3.2. Mesh model

The destination of the 3D model has not only the objective the communication on the site, but it also has a scientific ambition. To meet these two objectives, we had to develop models with two levels of detail, a geometric model of the entire fortress and mesh models. However, the discontinuities of the point cloud from the acquisition do not define continuous meshes. Indeed, there is no immediate interest to create meshes which parts will be empty. For the remainder of the project, designing a mesh model is mostly automated, processing, negligible compared to the geometric model, can be done later with the necessary complementary measures. However, we examined some issues concerning texturing meshed models and their broadcasts.

While the texturing of the geometric model has been made with generic textures, mesh models are adapted to the real texture projection since they do not suffer from excessive distortions. In [7,8], methods are proposed to obtain reliable representations. According to the level of detail of meshes, but also the presence or not of characteristic points, it may be difficult to select precisely homologous points between images and meshes, it is well known that it is necessary to pick at least six points distributed homogeneously on the image.

One of the difficulties encountered in the creation of 3D model is the diffusion and use of digital projects for the recipients. Indeed, for the archaeologist or historian, the use of 3D model is a great help to scientific analysis and develops hypotheses. Unfortunately, restoration specialists are generally not experts in 3D modeling and therefore they have no experience in handling 3D data and even less editing software. Currently, there is a simple solution to use, that allows to manipulate the 3D models, developed by Adobe: Acrobat 3D. This allows generating 3D models, which are directly exploitable in Adobe reader. Free for the user, this solution seems essential for the future communication of models. However, in our work we found that the geometric model is, by definition, very simple, we encountered no complications to achieve a structured 3D PDF layers. In addition, using the attachments utility it is possible to encapsulate multiple files 3D PDF in a single document. For the consultation of meshed walls, the 3D PDF is adapted, as we can see in figure 7, because the object is simple. When it comes to navigating a maze of space, manipulation of the model becomes unmanageable for the ordinary user. That is why we have made animations to allow the visit of galleries. The animation allows a precise presentation at a specific scenario.

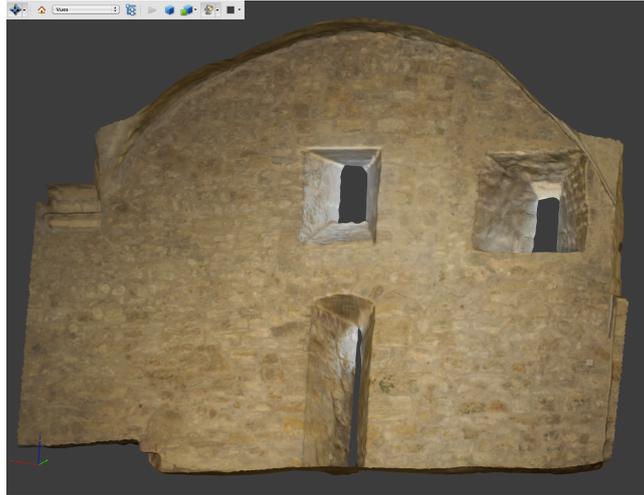


Figure 7: partial mesh model presented in Pdf3D for archaeologists

4. VIRTUAL VISITE

This chapter presents the different stages of the realization of a virtual tour based on spherical panorama. For the digital enhancement of the fortress, we found that the results of this method could respond appropriately to the problems of this project. Contrary to augmented reality, this means of communication does not require a significant financial investment and the production is relatively simple, so we decided to test this principle of virtual tour to the fortress.

Compared to video, spherical panoramic present some advantages. Indeed, for the visitor, navigation is fully controlled either in terms of duration of the visit, speed of rotation, angle of view and zoom on the points of interest or progression by selection of hotspots. In addition, the virtual tour allows manipulating less large than those video files, which is an advantage to the level of the diffusion via the Internet. Once chosen areas, the settings of the panoramic influence the positioning of the acquisition system. Then, the scenario envisaged for the visit guides on the choice of the shots. A decisive parameter concerns the Radiometry of shots. Indeed, for an Assembly of quality and homogeneity of the spherical panorama, it is necessary to achieve the photos in the same light conditions. A first Assembly treatment, on-site, is recommended to ensure the convergence of the calculations to a suitable solution geometrically and radiometrically with the two applications. It is possible to overcome quickly, the computational difficulties due to a missing photo or an unsuitable radiometry because the system is still in its initial acquisition position.

When panoramas are created and controlled, the export must be performed for integration into the virtual tour. Figure 8 gives an overview of navigation interface we proposed.

Beyond the format, the image resolution is a key parameter since it will define, in large part, the size of output file and therefore the weight of the virtual tour. The answer to this problem is not as simple as in many fields, it is still a compromise between size, weight and quality and therefore spherical panoramic virtual tour. Several parameters must be taken into account as the height of the viewer window, the zoom level and viewing in full screen.



Figure 8: Navigation interface of the virtual tour of the GuardRoom.

5. CONCLUSION

Cultural heritage representation is a wide field that includes, as users, requiring scientists and simple audience. In this paper we proposed several methods to manage each point of view in one acquisition step. This documentation project started in 2010 and will take several years to be completed as well. Precise meshes are dedicated to allow new reconstruction hypothesis to let figure throw other 3D model of ancient periods of the fortress. Simplified 3D model, animations and panorama give opportunity to spectators to virtually visit and to discover in a different way such impressing heritage.

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