3D MODEL FOR HISTORIC RECONSTRUCTION AND ARCHAEOLOGICAL KNOWLEDGE DISSEMINATION: THE NIEDERMUNSTER ABBEY'S PROJECT (ALSACE, FRANCE)

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ABSTRACT:

This paper describes the efficient combination of topographical surveying techniques, photogrammetric drawings and laser scanning point cloud acquisition for constitution of a three-dimensional model of an historical site, the Abbey of Niedermunster, in its current state. This site is remarkable all over its architecture and its history, but today only ruins remain. Without works of passionate archaeologist there would not remain much more than old stones. In this background, it has been decided to digitize all existing material and knowledge of this particular monument and site. At the same time, research collaboration was launched to promote the site and notably the scientific elements gathered throughout different archaeological excavations. The paper describes different stages of site digitizing up to the constitution of a virtual three-dimensional model.

1. INTRODUCTION

1.1 Context

This paper introduces the efficient combination of topographical surveying techniques, photogrammetric drawings and laser scanning point cloud acquisition for the constitution of a three-dimensional model of the Abbey of Niedermunster, in its current state.

The model has been then used as initial hypotheses for the reconstruction of the model of the Abbey in its original state. An interesting photo-model could be generated as well.

The paper shows also how a careful organisation of the data acquisition stages has been managed for constitution of a pedagogic tool based on the knowledge of the site. This information system includes high level archaeological works performed for several decades as well as existent data of accurate and recent surveys.

1.2 Location

Located at the bottom of the Mount Sainte - Odile, the Abbey of Niedermunster, Alsace, France, can be considered as the origin of the sanctuary. Built between 1150 and 1180 AD, the roman style Abbey was devastated during the War of the Peasants (1525) and by two fires, in 1542 and 1572. The site was then used then as quarry until the XIXth century. The great western massif of the basilica, still in elevation, and the relics of the crypt allow to imagine the beauty of original buildings. A legend gives an explanation of foundation of the Abbey. A camel was carrying on his side a big crucifix reliquary. When he stopped on the site of the Abbey, the legend says that the crucifix indicated the location of the holy site.

From an architectural point of view, it's a construction in three double spans with alternation of piles and two massive towers supervising the porch, at its Westside. The transept is overlapping; the rectangular chorus is surrounded by square chapels. The Abbey also includes a big crypt which was consecrated in 1180.

This site is therefore remarkable all over its architecture and its history, but today remains in the state of vestiges, and without works of passionate archaeologist there would not remain much more than old stones. Dimensions, which can be considered as impressive for the being discussed Abbey type (3000 sq.m.) offer us a very accessible object for study. Beside the size of the site, the important height differences between the different parts can be considered as a particularity of the project.

1.3 Research collaboration

In this background, it has been decided to digitize all existing material and knowledge on this particular monument and site. At the same time, we took up research collaboration with the local authorities (County of Rosheim) to promote the site and notably the scientific elements gathered throughout different archaeological excavations. The methods of topographical surveying were massively put in contribution particularly by combining the most recent data acquisition techniques.

The paper describes different stages of site digitizing beginning with classical topographic survey (angles and distance measuring) up to 3D laser scanning. Topographical location and 3D point clouds act as the two main components for the constitution of a virtual three-dimensional model.

2. DOCUMENTATION

The drawing of a topographic map was in the 1980's supervised by the archaeologist, M. Jacques Preiss, in charge of the site (Preiss, J., 1990). This map contains the topographic details still visible, as well as some disappeared parts which were symmetrically redrawn. To confirm the archaeologist hypotheses, different surveying techniques have been undertaken. The lower part of the site, notably containing the crypt is not represented in this documentation. In short, it is a 2D map without any heights information, while the site presents differences of heights of several meters according to the diverse parts.

The archaeological methods of documentation are based on the former excavation note-books representing the various elements as a geo-referenced sketch. These sketches concern the parts which are not accessible anymore today but which are very interesting for the future site information system.

Finally, the archaeologist proposed hypotheses of reconstruction of the whole site. This last part of the documentation will be used as a basis for a future stage of digital site reconstruction.

3. SITE DESCRIPTION

3.1 Charasteristics

The site extends over a surface about 70 m. per 45 m. It contains extensions which are hardly recognizable in its current state. A barn of the beginning of the XXth century will also be integrated into the site.

Figure 1 is an aerial view of the site and Figure 2, the representation in plan of the main parts.

In the available documentation, the various stony piles which have to be listed and resulting from various periods of excavations were represented.

The impressive western block is the only part still in place. The vestiges up to the first floor only remain. It consists, in fact, in a hall of entrance with a characteristic vault and in stairwells containing spiral staircases, also bent, and allowing the access to the superior level. These two stairwells remain intact and therefore are interesting for the modeling phase.

Figure 1. Aerial view of the site
(from a camera fixed at a balloon)

The straight staircases allowing the access to the crypt are also in a good state of conservation, though exposed and uncovered. The chapter room is recognizable only by some elements of walls and is used as stocking of goods of excavations vestiges. Finally, the bases of some pillars of the nave are still visible. Some have a circular foundation while others have cross foundation.

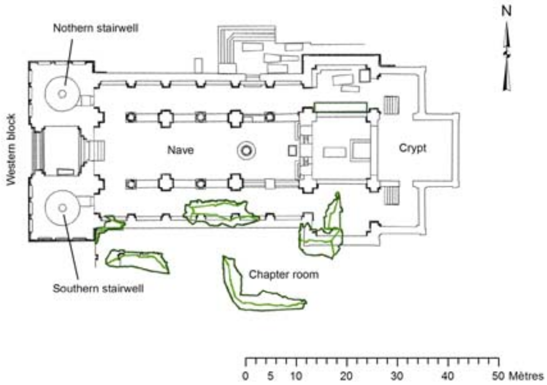

Figure 2. Main parts of the Abbey

3.2 The project

The project contains several stages:
The first stage consists in the documentation of the site in its current state, with the aim of establishing an interactive photomodel. The expected photomodel allows a better comprehension of the site concerning its dimensions, its details and its construction mode. The photomodel has been elaborated on the basis of a structured virtual 3D model. The structure was designed to be integrated in a more complete information system. The constitution of the photomodel was realized by setting up an elaborated methodology. From the user point of view, the objectives of the model are far beyond a single photomodel. Furthermore, the combined use of several instruments like a total station, a 3D scanner, a total imaging station, etc. allows the definition of best adapted technologies and methodologies for every digitizing type and particularly for every type of feature to be plotted. The modeling phase was also defined in order to be the best adapted structure of the information system.

Some parts which remain in a good state of preservation have been modeled in a very simple way with planar faces, textured afterwards. These faces were only defined through the measuring of some points. The modeling stage has then been easy-to-do.

Other parts, more degraded, require more advanced modeling methods. In these cases, extractions of the initial measured point clouds have been meshed (Figure 3).

The paper describes exclusively this long first stage.

The second scheduled stage will consist of the reconstruction of the abbey in its hypothetical historic configuration.

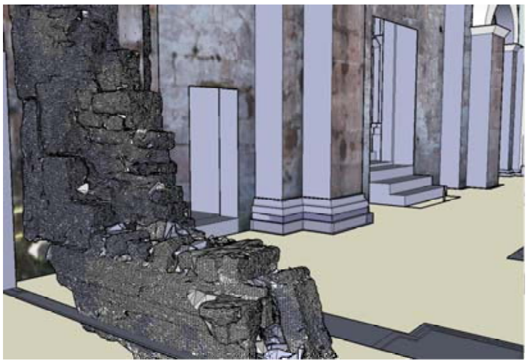

Figure 3. CAD and meshed structure

The very long digitizing phases concern only the first stage, the second will be realized by means of modelers.

The project is finally established to grant an access to the monument for visitors in a virtual way. Indeed, the opening of the site itself is not planned for the moment for evident access management reasons and also to avoid inevitable damages. Hence, a virtual visit will be possible through an interactive terminal at the "Mount Sainte-Odile" which is the main convent with which our site is connected.

4. DATA ACQUISITION

4.1 Topographic survey

During the first stage, the archive archaeological records have been geo-referenced in a Geographical Information System (GIS) thanks to an accurate topographic survey. This very important stage has been entirely redefined for the circumstance. Indeed, for an efficient archiving, the survey of every point has been photographed. So, in case of doubt during the results interpretation, the archaeologist will directly be able to refer to the image to well identify the corresponding point on the site.

This topographic acquisition of 2D points (with indication of the height) has been made by using total station and allowed an accurate positioning of the various and distinctive elements of the ruins. It was also very important during the referencing phase. All excavations made previously and all particular features can now be integrated into a next enhanced version of the model. The digitizing has been made under the control of the archaeologist in charge of the site. He notably clarified if the found element was in its initial and historic position or if it was already "repositioned" during known works of reconstruction. The topographic map has been adjusted in plan and in height thanks to the determination of reference points measured by GPS. For the further stage of modelling, the topographic survey also allowed the simple extraction of height values of some points along still existent elements. These 3D outlines have then been used during the constitution of the digital terrain model (DTM).

Some particular elements as the spiral staircases of the western massif have been digitized by using mixed methods: tacheometry for the digitizing of the outlines of the stairs, total station surveying (Trimble VX) and 3D scanning (Trimble GX) for the scanning of the vaults. The use of these three methods notably allowed to compare them and to deduct specifications for each of them according to the particular context. Figure 4 shows the result of the digitizing of a stairwell in the occidental block.

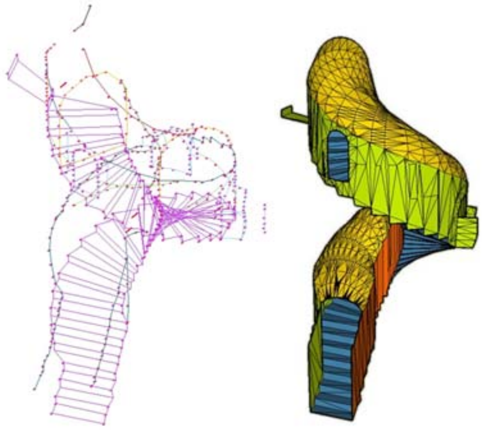

Figure 4. Northern stairwell (seen in Figure 2) in (a) wireframe and (b) meshed representation

4.2 3D Scanning

This second stage of scanning has been accomplished in two steps: scanning of the abbey's area in current state, followed by supplementary scanning site details.

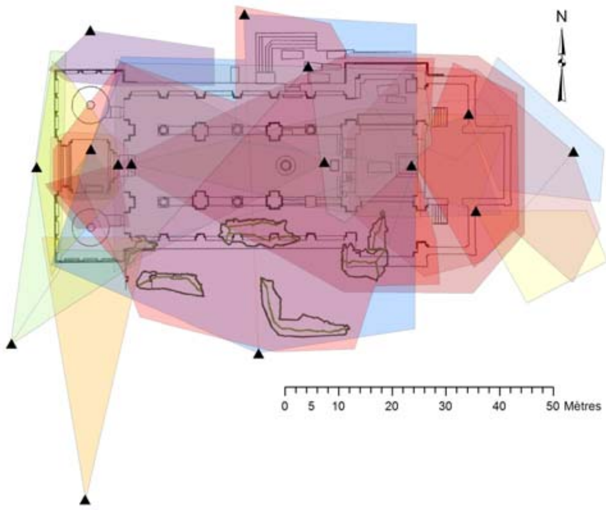

Figure 5. Scanner stations for data acquisition

Data acquisition consists of scanning the complete site by using a 3D TLS. A "Trimble GX" scanner has been used for that purpose. It allowed the acquisition of point clouds for which the density was defined by the operator according to the expected degree of details. A grid density of 1000 points per square meter has been used in the general case. The obtained point clouds were geo-referenced, the information for every point was thus constituted by X, Y and Z coordinates in the ground coordinate system, completed by intensity or color.

For the complete digitizing of the site, about 15 scanner positions have been used, which resulted in 40 different scans, for a total amount of approximately 30 million points. Figure 5 shows the distribution of the various used scanner positions.

4.3 Photogrammetry

The third stage consists in a supplementary plotting by photogrammetric techniques. These are used under their terrestrial form by taking a huge quantity of photographs of all of the building details. These last photographs, being orientated will allow the measurement of details of the most important parts of building with a stone by stone very accurate digitizing. They also allow to create exhaustive sets of images intended for the reliable texture mapping of the final model.

Balloon photogrammetry was also implemented. Photographs have been taken from a captive balloon (seen on Figure 6), the position of the camera having been directly measured during stage of image acquisition.

The previous plots were completed by photogrammetric plottings from aerial photographs taken from a captive airship. This last one was able to be regularly moved by about ten meters in the West-East direction, which allowed a recovering rate in the same direction from approximately 70 percent. With the relative small dimension of the site, only a single band was needed. It was completed by convergent photographs.

4.4 Conclusion

The various data acquisitions were very complementary and give very precise indications: on the location X, Y (Z) of single points for the first mode, on the shape (often complex), the surfaces type and the height of the three-dimensional objects for the second mode and, finally, on textures and the composition of groups for the last method.

Figure 6. Images captured from captive balloon

The aerial photogrammetry was then used as a supplementary technology of stereo-plotting, but also for providing catalogue of very important texture elements. During this stage, the initial pictures intended for communication were used in a purpose of photogrammetric accurate stereo-plotting.

5. MODELING

5.1 In general

The data acquisition was followed by data processing operations allowing to obtain a 3D model of the ruins segmented in various layers.

The classic processing has been applied to the different datasets. We watched particularly the structure of the data. Datasets were grouped in components according to a data model specified to the various constitutive elements in a 3D GIS. The 3D GIS is aimed to be used as basic system for the design of an educational application system.

The digitized elements were accordingly classified onto specific layers.

5.2 Workflow

While the processing of topographic data follows a classic plan, the treatment of the TLS point clouds is detailed in the following. Figure 7 shows the workflow used for point cloud processing.

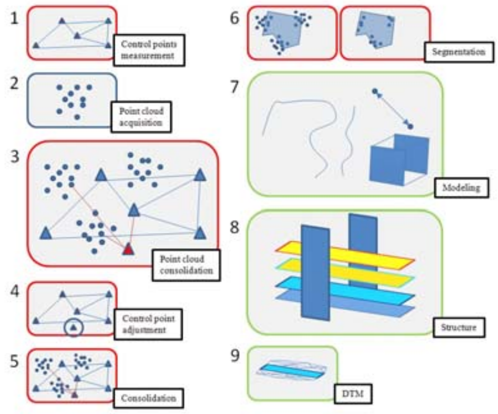

Figure 7. Point cloud processing

The successive stages were:

1. Reference points definition with GPS.
2. Data acquisition with 3D scanner with setting of the parameters of measurement according to the expected level of details.
3. Consolidation of the different clouds from reference points and determination of the coordinates of new added scanner positions.
4. Control of the scanner position coordinates by topographic accurate surveying.
5. New clouds consolidation according to these supplementary new coordinates.
6. Segmentation into specific elements according to the structure and to the predefined and adopted layer decomposition.
7. Profiles, shapes dimensions, heights extraction from clouds.
8. Modeling according to the structure.
9. Contour lines extraction for DTM.

After cleaning and deletion of the not significant points (filtering, noise reduction), the point clouds were segmented in separate elements of the dissimilar components. The volumes were obtained from the outlines or from the different edges by extrusion. The ground lines were adjusted to the DTM.

These treatments give place to three-dimensional elements bounded by faces. These faces were very important in the adopted data model. Indeed realistic textures were mapped on them. The processing of the point clouds were made by using the *Realworks Survey* software package.

Parts in ruin were modeled with meshed surfaces obtained directly from the filtered point clouds. *3DReshaper* was used to obtain these results.

Thus, the final model contains remaining parts in a state called “such as built” geometrically modeled by means of faces. The degraded parts were modeled by using meshed surfaces.

Other complements to data processing were notably made in the case of circular pillars or the other curved parts which can be modeled by extrusion from profiles.

Finally, textures were applied to the different faces from detailed photos.

5.3 3D model

The geometric and semantic model was based on a data model structured for an exploitation in a 3D GIS.

5.3.1 Description of data model

Hence, the abbey is constituted by internal spaces. These are defined as being particular places of the building, characterized according to their historic use. Every internal space can be decomposed into sub-spaces which are subdivisions of the internal space and constitute not closed volumes of walls, but were included between several physical objects. They are called: "spans". The internal spaces are decomposed in sub-spaces consisting in volume objects and/or surface objects.

A volume object is an object formed by a set of faces whose planar projection is a polygon. The extrusion or intrusion of such polygon defines a volume. The volume objects can be either independent from any other structure, or share common faces. The volume object can be either an outgoing element or an incoming element. It can still, into the particular case of the Abbey, be a column, a pillar or a pilaster, etc. These all are vertical supports themselves consisted of 3 subsections.

A surface object is an object formed by several faces, but not constituting a volume. It is similar to a plan presenting two faces: inner side/outer side, lower side/upper side. The surface object forms a separation between two different spaces: inside / outside, inside/upper side, etc.

Thus, according to previous both definitions, a volume object consist in a set of surface objects.

Surface objects as well as the extruded or intruded volume objects consist of a succession of diverse surface elements:

- Internal element of face: oriented to the internal space of the building.
- Outside element of face: oriented to the outside space of the building. It can involve here the natural outside space or the outside space constituted by another building (for example, in the South of the abbey, we shall find an outside element of face directed to the North gallery of the monument).
- Upper element of face: situated upstream to the axis of eyes.
- Lower element of face: situated downstream to the axis of eyes.
- Interface: face of connection between several elements (for example: surface occupied by a pilaster on a wall: this surface belongs at the same moment to the pilaster and to the wall, and is defined as "interface").

To identify a component on the site and consequently in the model we had to propose a decomposition of the 3D world. Thus, the space is decomposed at first in horizontal zones (according to their affectation), then vertically according to the constitution of element.

6. 3D GIS OF THE MONUMENT

6.1 GIS data integration

The model such as presented previously has been structured to be integrated into 3D GIS. Every constituent element of the abbey has been transformed into a component (Figure 8). So, it could be easily transferred separately in the GIS. Appropriate attributes may then be associated to each component. The implementation of this 3D GIS is the first stage of the constitution of a knowledge information system about the site. Indeed, it is going to allow the integration and the association of every component of the descriptive data, in form of attributes, but also external data such as images. For example, we can also associate all the results of the previous archaeological works like excavations, reconstructions, historic documentation, etc.

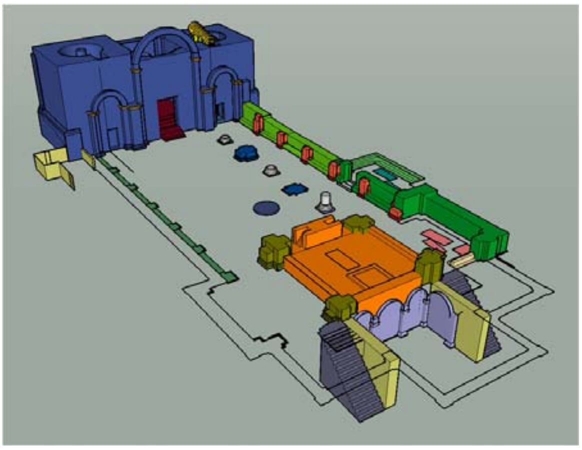

Figure 8. Component structure for GIS integration

6.2 GIS functionalities

With the GIS, the model can be analyzed in different ways.

Indeed, while the 3D model offers visualization and interesting animation possibilities, the GIS allows to localize information inside the model and to return this information on demand.

Partial visualizations of the site are possible according to the layer structure of the model. With complementary information related to the model (not realized at present time) it will be possible to simulate new rendered models according to different analyzing parameters.

6.3 Photographic documentation

As further information, a large number of photos were taken from all the parts of the monument.

The process of photographic documentation was particularly studied. Indeed, the position of each camera was exactly measured during the recording. The knowledge of these points of view positions and the recording of camera parameters gives new solutions for texture mapping. Indeed, the recording of the parameters allow at the same time to have very precise and easily applicable textures, but also allow to configure the visualization to recreate the same perspective as that while taking the images. This method lets expect new perspectives by the combination of a 3D model and images. Indeed, the process of automatic texture mapping can be envisaged according to the point of view. Hence, the realism will be increased (Figure 9).

Figure 9. 3D model with texture application

7. CONCLUSIONS

The implementation of this model was an opportunity to experiment, to combine and to organize various methods of data acquisition. After data processing, a 3D model structured in components was built. This model has been integrated into a 3D GIS allowing to make geo-localized treatments and also to associate additional attributes or very rich external data to these same components. A particular care was brought to the additional photographic statement on one hand for the fine application of textures, but also to test a new method of real time texture mapping. The 3D model is completely navigable and notably contains the modeling of two arched stairwells. This model composes the basis for a future knowledge and information system about the site, even of a future interactive information terminal intended for the general public. This 3D model of the still existing state will serve as basis for the second phase of work more centered on the complete virtual reconstruction of the site. Indeed, hypotheses of the archaeologists in charge of the site have already given place to sketches of the complete site. The work on the model containing more easily extractible metric data will allow the confirmation of the emitted hypotheses on historic construction methods. Finally, these interdisciplinary works allowed to work with specialists stemming from very diverse circles. When historians, archaeologists, architects, monks as well as a cell of cultural heritage valuation and finally topographers work on and for the same site, the personal and human enrichment is very stimulating.

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