MULTIPLE USES OF A 3D POINT CLOUD: THE CASTLE OF FRANCHIMONT (PROVINCE OF LIÈGE, BELGIUM)

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ABSTRACT: This paper presents the identified obstacles, needs and selected solutions for the study of the medieval castle of Franchimont, located in the province of Liège (Belgium). After taking into account the requirements from all the disciplines at work as well as the problems that would have to be tackled, the creation of a 3D point cloud was decided. This solution would be able to deal with the characteristics and needs of a research involving building archaeology and related fields. The decision was made in order to manage all of the available data and to provide a common working tool for every involved cultural heritage actor. To achieve this, the elaboration of an Archaeological Information System based on 3D point clouds as a common virtual workspace is being taken into consideration.

INTRODUCTION

The medieval castle of Franchimont (Province of Liège, Belgium) is currently being investigated under multiple angles. The origins of this cultural heritage site are not well known. Based on the written sources, two hypotheses have been established dating the beginning of the construction of the castle either to the tenth century or the eleventh century. Over the course of the next few centuries, the buildings were modified, partially destroyed and reconstructed and new structures were added. By the end of the eighth century, the castle was abandoned and its ruined state was officially recorded by a surveyor (Hoffsummer, 2016).
The ruins of the castle of Franchimont quickly attracted artists and photographers. This allows for an important iconographic coverage documenting the successive stages of the destructions. Additionally, the beginning of the twentieth century marks the beginning of archaeological investigations: several researchers and various sectors have been studied. At the same time, restoration works have been undertaken where it was needed. For the last fifty years, the *Compagnons de Franchimont*, a not-for-profit association, has been taken care of archaeological investigations, restoration works and opening the site for visitors (Hoffsummer, 2016).
The University of Liège has been implicated with the research carried out at the castle in various ways, e.g. excavations, building archaeology and topographical surveys (fig. 1).

1. CULTURAL HERITAGE ACTORS

Since the creation of the *Compagnons de Franchimont* association, interventions have been undertaken regularly on the cultural heritage site. These may include excavations, restorations, reparations and adapting the site for tourist purposes. For these various actions, other than the association's members, other actors working in the cultural heritage field have been involved.

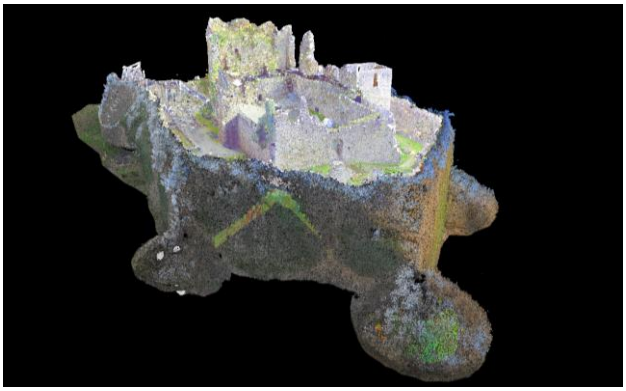

Figure 1. 3D point cloud of the castle of Franchimont, view from the north-west. The stairs are visible through transparency as they are located inside of the outer wall.

However, these mostly punctual works have not always been recorded and the data was also not assembled into one common and global documentation system. This has led to multiple data collections that are not always available to other cultural heritage actors.

1.1 Archaeological investigations

Several excavations and building archaeological studies have been carried out over the years. These are characterized by different numbering systems over the years, repeating numbers that do not refer to corresponding elements or a common stratigraphical level. Also, as the excavated sections have been filled in, current analysis can only be executed based on photographs taken during the digs, on plan and cross-section drawings as well as on the related excavations journals. However, it can be quite difficult to understand some of the theories and conclusions as they can hardly be verified on site. Also, the research on this castle is not over yet: new excavations should take place later this year.

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1.2 Architecture

Architects are also likely to be working on the castle of Franchimont. Indeed, some thinking has been done so that some sectors would be more visitor friendly. As the height differences are quite important and nothing over the first floor can be safely accessed, various possibilities have been played through. Of course, as this cultural heritage site cannot be modified in its nature, the architects need to work hand in hand with archaeologists and restorers in order to obtain the most adequate construction (Lilien, 2002).
Also, at the beginning of the year 2017, some ideas have been worked out by architecture students of the University of Liège to make the castle more attractive for tourists. These have been based on data provided by the newly acquired 3D point cloud as they provide the most recent recording of the whole site and as it allowed taking measurements in dangerous or inaccessible zones.

1.3 Restoration - conservation

The castle of Franchimont lost its defensive and political power at the end of the seventeenth century. This led to quite systematic destructions all over the site as the locals reused the building materials. Weather and time erosion also took their toll on the medieval structures. By the middle of the nineteenth century, the castle of Franchimont was a popular site for romantic artists and photographers (Hoffsummer, 2016). Even nowadays, some parts are likely to collapse. To preserve this cultural heritage, restoration and conservation works are punctually being carried out.
At the same time, the *Compagnons de Franchimont* association also supervises reconstruction works based on historical documents and comparisons with similar cultural heritage sites. This has led to the reallocation of the wall tower at the main entrance: in addition to its reconstruction, it was transformed in order to welcome the visitors and to provide a small exhibition hall informing about the history of the site and the discoveries that have been made (Hoffsummer, 2016).

1.4 Communication

In order to make the region more attractive for tourists, the castle of Franchimont is an important factor. Therefore, as previously mentioned efforts are made to render the site and the different structures as accessible and interesting as possible.
With this in mind, a 3D virtual reconstruction has been thought out and commissioned at a professional 3D graphics company. The castle of Logne (Province of Liège, Belgium) was previously remodelled by the same firm. The final result, although it did not present an accurate depiction of the destructed sections, allowed visitors to picture the castle how it probably may have looked like. The film shown as part of the visit of the site also included the surrounding landscape as it may have been. The combination of the reconstructed castle and the adapted scenery helps to gain a better understanding of the impact and the importance that it had while it was still standing (Wéry, 2015).

2. NEEDS AND ISSUES

As of lately, more and more projects as well as cultural heritage actors are linked to the castle of Franchimont. However, the different undertakings are not executed at the same time and most of the participants do not specifically know each other. In order to develop a common workspace for all of the workers that would enable everyone to work with the same documents and the most up to date data, it was necessary to obtain a system that would fit the needs and specifications of every field. This would also allow for mutual exchange and it could be used as a discussion basis.
To achieve such a common workspace, the actors from the various fields were asked to list all of the requirements their work depends upon as well as the issues they would have to face. The following lists have been summed up into larger categories as some of the entries repeated themselves and others partially overlapped which allowed grouping them into broader concepts.

2.1 Requirements

As the different cultural heritage actors all deal with spatial and historic issues, their requirements mainly referred to up to date data, historical accuracy as well as plans and cross-sections. However, concerning the spatial studies and the renewal of the tourist offer, these features only impact on the work of some of the participants.

2.1.1 Checking data accessibility: this feature is key for precise and accurate work and research. Indeed, if an architect or a restorer does not have access to the latest discoveries or modifications, it can infer their thought process or the conditions of their work. As for an archaeologist, it is necessary to be aware of the data that was previously collected in order to be able to understand the links that could exist between various entities. Consequently, if they do not have access to the latest data, their research could be less effective and complete. Also, if new information is brought to light, it is important to provide at least some of it to the visitors. As the site is open for visits and one of the goals of archaeological research is to inform the citizens about their history. Therefore, it would be of big help to renew as soon as possible outdated information.

2.1.2 New geometric data: as the primary feature all of the cultural heritage actors have to work with is space, it is obvious that most of them are going to need plans and cross-sections. However, depending on the end use that would be made of them, the different work fields have different requirements for those plans and cross-sections. Indeed, archaeologists will be more interested with certain features that will enable them to understand the history of the constructions. These same characteristics will also interest restorer to a certain point. Nevertheless, they will also, as will architects, need plans and cross-sections that contain the architectural and geometric information that will allow them to develop and adapt their ideas to the reality of the castle. Furthermore, these documents can be used to illustrate information panels displayed for the visitors.

2.1.3 Architectural modification support: to preserve the site for future generations, some restoration and consolidation works are inevitable. However, they cannot be executed if the site is to be irrevocably modified or if the general aspect of the castle is too altered with new additions. As the site is also regularly adapted to the visitors so that they can better move around and get access to specific zones. Therefore, architects have to take into consideration all of these characteristics when they create new installations. The same aspects have to be thought of for the construction materials that are going to be used so that the new elements can be easily identified as added structures.

2.1.4 Research support: as previously mentioned, the spatial aspect is an important characteristic for each the involved cultural heritage actors. Additionally, the archaeological research that is currently carried out at the castle of Franchimont is particularly centred on the study of spatial relations within the castle itself as well as with its surroundings (Luczfalvy Jancsó et al., 2016; McManama-Kearin, 2013, 2012). Therefore, a workspace able to combine different types of spatial data would be beneficial. This feature could also very well be used for restoration purposes as it could provide insight on the location or the height of structures they are working on.

2.1.5 Communication support: the castle of Franchimont is more and more adapted for visitors. In the past, a welcoming centre has been installed into an ancient wall tower. This space is used as a ticket office (fig. 2) with additional shop as well as an exhibition hall for archaeological discoveries and for a quick history of the site (Hoffsummer, 2016).

Figure 2. The ticket office area at the castle of Franchimont.

The 3D reconstruction that is currently in the works will also be visible in this space. The renewal of the tourist offer will also be an opportunity to inform the visitors on the research and restoration works as well as conservation efforts that have been carried out at the castle. This will provide them with interesting insight on the work that contributes to the preservation and the understanding of the castle. This additional information might heighten the curiosity of the visitors and even lead those who already have explored the castle to do it again under new circumstances.

2.2 Obstacles

As it was done for the requirements, the issues that were mentioned by the participants have been grouped into larger concepts. The first two, the height and stability problems, have an impact on the work of all of the cultural heritage actors. The other three, namely the individual and punctual actions, the inconsistent documentation as well as the partially digitalised data, mostly affect the archaeological and architectural work as well as the restorations and conservation efforts.

2.2.1 Height: the cultural heritage site of Franchimont is located on a rocky spur that elevates itself over the Hoëgne river and the Wayai river valleys (Hoffsummer, 2016). The lowest point of the castle is located at 211 meters altitude. On the other hand, the highest point dominates the ruins at 260 meters. However, the castle can only be visited up to the first floor, corresponding to a height of 241 meters. Additionally, it is quite dangerous to climb up the remaining wall which makes it impossible to examine and study the higher parts directly.

2.2.2 Stability: the mainly preserved parts of the castle of Franchimont are the outer wall along with its casemates as well as the external building walls. As most of the inner support structures do not exist anymore, the stability of the remains is not assured, especially for the higher sections. The outer wall has been partly plundered from its construction materials since the castle had been abandoned, which leads quite often to falling stones. One of the casemates has already partly collapsed and is closed for the visitors (fig. 3). All of the above mentioned points need constant supervision and monitoring in order to assure the safety of the people working on site as well as of the tourists. Moreover, consolidation and reparation activities have to take place as soon as it is necessary.

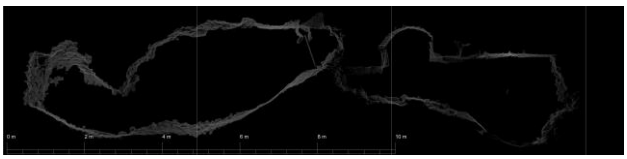

Figure 3. West-east cross-section of the north casemate showing the collapsed ceiling.

2.2.3 Intellectual propriety and data accessibility: since the beginning of the twentieth century, the castle of Franchimont has captured the attention of scholars, archaeologists, historians, architects, artists and photographers. In the last forty years, students have executed some of their research work on this site. All of this has also led to numerous documents and data. However, as most of these actions have been executed individually from one another, sometimes only concentrated on one specific aspect or section, it can from time to time be challenging to understand links between those different studies.

2.2.4 Inconsistent documentation: as previously mentioned, most of the research and restoration / consolidation / reconstruction work that was done for a bit more than hundred years has been executed by various people. Therefore, it is highly possible that current researchers and workers do not have access to all of the documents and data that was generated during those operations. Also, as they were recorded at different time periods and with specific goals in mind, elements that would be of importance for current research types may not be included. Also, not every action is published which can lead to missing information. In case of an excavation, due to its destructive nature, the data can therefore be irrevocably lost. If, by chance, the original data is recovered, it still needs to be understood, which can sometimes be complicated if none of the mission's participants is available to provide some help.

Additionally, since every type of analyse and study traditionally uses its own specific tools and methods, it appeared that the collected data and information would be numerous and consisting of various kinds of documents. Another factor that had to be kept in mind was the subjective nature of archaeological drawing, one of the most utilized techniques in building archaeology (Arlaud and Burnouf, 1993; Schuller, 2002; Eßer et al., 2011; Boto-Varela et al., 2012; Alby, 2015). Indeed, since an archaeologist would produce a range of information that would also be used later on, he needs to provide documentation that can be exploited for the other goals. However, as he is the one that determines the important features that have to be recorded in plans, cross sections or drawings, other details that could be of consequence further along would then have to be checked again on the site and added to the already existing documentation. In order to collect the gathered data and information and to make them available for every work step, a solution that could satisfy and be of use to all the involved parties had to be found.

2.2.5 Partially digitalised data: nowadays, most of the planning and publication work is based on digital documents. Therefore, the data that have not previously been digitalised needs to be taken care of. To be compatible with various types of geographic and spatial data, the paper versions have to be vectorised, an operation that requires manual computer-aided drawing. Otherwise, the documents cannot be used as interactively as the vectorised ones.

3. 3D DIGITISATION

After the analysis of the needs and issues that the cultural heritage actors would be facing, it was concluded that the creation of a 3D digitisation of the castle of Franchimont would provide suitable solutions (fig. 1). Indeed, as for the obstacles that hinder the on site work, namely the height and stability issues, they can be overcome with this method. It was produced with a 3D laser scanner, mainly used on the ground level and on the accessible elevated parts of the castle, as well as photogrammetry with pictures taken by drone in order to cover the highest zones of this site (Poux et al., 2016). Through the combination of data acquisition with a 3D laser scanner as well as with drone footage, we were able to cover most of this cultural heritage site. Although it does not completely replace a direct access and study of the remains (Arlaud and Burnouf, 1993; Schuller, 2002; Héno et al., 2010; Boto-Varela et al., 2012; Limp, 2016; Luczfalvy Jancsó et al., 2016). Nevertheless, considering the stability problems and the height complications, it at least enables the cultural heritage actors to virtually study these sections. The following features and usages of this type of 3D digitisation seemed to meet best the needs of a research carried out on a cultural heritage site: objective documentation, multiple visualisation possibilities, various exploitation possibilities, precision, georeferenced model, colorization, distance and angle measuring, plan, cross section and volumetric data extraction as well as possible combinations with other spatial documents and analyses (LiDAR, GIS). These characteristics would enable the researchers and cultural heritage actors to study the evolution of the architecture, the volumes or the spatial relations in and outside of the castle (Arlaud and Burnouf, 1993; Schuller, 2002; Héno et al., 2010; Boto-Varela et al., 2012; Canciani and Saccone, 2012; McManama-Kearin, 2012; Salvador and Vitti, 2012; McManama-Kearin, 2013; De Kleijn et al., 2016).
Also, a basic 3D point cloud does not satisfy all of the above mentioned characteristics: for example, the digitisation does not help with missing or not vectorised data all the more if it concerns another type of information other than spatially driven. Therefore, it is necessary to add information to this point cloud by developing a system that would allow to query all of the available data, but not only (Luczfalvy Jancsó et al., 2016). Table 4 summarises the requirements, the obstacles linked to each of the needs as well as the solutions that are proposed to resolve the issues.

Requirements	***Obstacles***	***Solutions***
Checking data availability	- Intellectual propriety and data accessibility - Partially digitalised data	- Documents archiving - Geographic reference tool
New geometric data	- Height - Stability	- 3D digitisation - Geographic reference tool
Architectural modification support	- Height - Inconsistent documentation - Partially digitalised data	- 3D digitisation - Documents archiving - Interpretation - Spatial analysis - Geographic reference tool - 3D modelling
Research support	- Height - Stability - Intellectual propriety and data accessibility - Inconsistent documentation - Partially digitalised data	- 3D digitisation - Documents archiving - Interpretation - Spatial analysis - Geographic reference tool - 3D modelling
Communication support	- Height - Stability	- 3D modelling

Table 4. Summary of the requirements, the obstacles they encounter and the proposed solutions

3.1 Multiple Uses

As (Luczfalvy Jancsó et al., 2016) has already stated such a system defined as Archaeological Information System (AIS) must be able to handle at least the following parameters: one or more 3D models, data storage, consultation and production, topographic setting and environmental analysis, time management, recording the workflow as well as the elaborated theories and lastly, flexibility so that it can be adapted following the users' needs. Moreover, as numerous cultural heritage actors are susceptible to use it, the AIS has to deal with the multivocality characteristic of this kind of data (Cripps, 2013).
The spatial component is at the centre of all of the fields dealing with cultural heritage. Therefore, it seems only logical that the 3D model serves as an interface to access and visualize the data that was entered into the AIS. This feature requires that the point cloud serves not only as a tool to explore and measure the castle of Franchimont, it also has to handle archiving, interpretation, spatial analysis and geographic reference tool functions.

3.1.1 Documents archiving: since the 3D point cloud is to provide access to all of the data, archiving possibilities have to be available. This is especially important because if further research or work are carried out at the castle, this new data will have to be added to the already existing one as it completes it. The medieval backing ovens represent an interesting case where multiple layers of information have been created. In 2014, a digitisation campaign was organised in order to scan the remains of these structures (fig. 5). This was necessary as a reconstruction project was carried out that saw the installation of modern ovens inside the space of the medieval ones and the front masonry was also recreated. As a consequence, the medieval parts are now invisible as well as inaccessible. A second digitisation campaign was led in 2016 to capture the modifications that had been made. Therefore, our 3D point cloud allows to visualize both states of the ovens and it serves as a digital archive for those aspects and the data that is linked to each of the states.

Figure 5. North-south cross-section through the western backing oven. The reconstruction is visible on the right side

In the end, for this example, one data repository is accessible with however two different temporal elements. As monitoring and restoration / consolidation / reconstruction are likely to happen again, this kind of archiving will be used again to preserve as much data as possible.

3.1.2 Interpretation: the ruins of the castle of Franchimont can be quite difficult to understand as only few textual sources exist. The same can be sais about ancient plans and maps of the layout of the site. The history of the walls is mostly read on the structures themselves (Schuller, 2002). To understand the evolution of the buildings, the bits of extracted information are interpreted. However, it is almost impossible to affirm with certainty that a theory is absolutely accurate. Consequently, multiple interpretations are possible. The AIS can then serve as a virtual interpretation ground to help verify or, on the contrary, disprove those that are not compatible with the available data.

3.1.3 Spatial analysis: the surroundings of the castle of Franchimont being quite undulating and in line with the protective role that was assigned to the site, spatial analysis including the landscape provide valuable information. As the remains are quite sparse, viewshed analysis (McManama-Kearin, 2012) can be executed from points at different heights, be they still preserved or virtually determined, to gauge the impact the castle had on its environment and inversely. This kind of analysis can only be executed if other geographic documents are linked to the castle's point cloud, e.g. LiDAR (fig. 6).

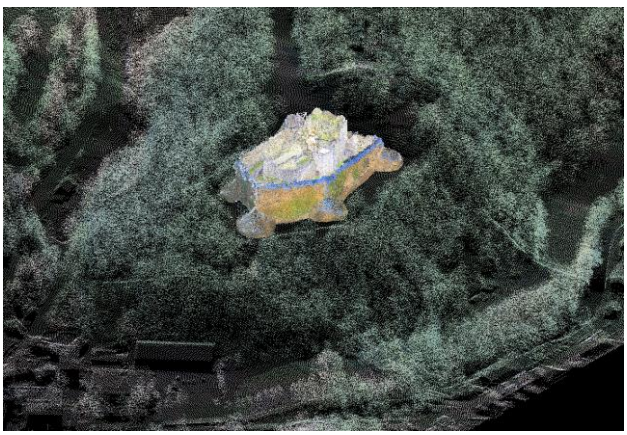

Figure 6. 3D point cloud of the castle of Franchimont combined with the coloured LiDAR data of the municipality of Theux.

3.1.4 Geographic reference tool: over the last century, quite a bit of research has been carried out at this cultural heritage site. Archaeologists, architects and restorers have all produced plans and cross-sections. Sometimes, the original locations referred to in those documents are not visible anymore as excavations have been filled in or elevations have collapsed. In this case, the 3D digitisation can serve as a reference tool to situate ancient maps or cross-sections that document an inaccessible space.

3.1.5 3D modelling: as previously mentioned, a 3D reconstruction is currently in the making. As a basis for this work, it has been decided to also use the point cloud of the castle of Franchimont. This provides a solid geometric base. Moreover, the modelling in itself in addition to other documents and data helps with the verification of a series of theories concerning the past aspect of the buildings.

CONCLUSION

After analysing the needs and obstacles that every cultural heritage actor would meet while working on the castle of Franchimont, a 3D digitisation seemed to bring forward the

most adequate solutions. Additionally, it will serve as a virtual workspace where all of the data can be consulted and theories can be tested. The combination of various types of data linked to the 3D digitisation is the basis of the Archaeological Information System (AIS) which purpose is to collect every bit of data to make it available on a unique platform instead of numerous files and analogue documents.

As spatiality is one of the main components, a 3D point cloud provides a precise reference tool for analysis as well as for the integration of other spatial and geographic documents. The temporal feature, another main component of cultural heritage, can also be integrated as multiple states of a zone can be stored simultaneously.

Therefore, the 3D point cloud acquired through 3D laser scanners and drone footage serves multiple purposes other than just virtual exploration and geometric data.

Future work will include applying the AIS to other castles in the province of Liège. These sites will allow us to test the possibilities and limits of an AIS based on point clouds when used in another context as every castle has its own particular geographical setting, history and available data pool. Also, not all of the mentioned cultural heritage actors are involved with those sites. However, others that are not currently part of the projects at the castle of Franchimont might be. This will be the opportunity to further develop the AIS.

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