

3D MODEL SUPPORTS ARCHAEOLOGICAL KNOWLEDGE BASE

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Abstract:

The paper describes the implementation of a 3D model of the Engelbourg castle in Thann, Alsace, France. During the last years, these ruins have been the subject of several thorough archaeological studies. They now constitute a very rich documentary base. The LSIIIT/TRIO team has been modeling the ruins and its surrounding environment for two years, using surveying, photogrammetry and TLS techniques. The model of the current state was formed with an important quality and geometric accuracy.

This paper presents firstly the various operations of field measurements and modeling, and especially the led thought about the structuring of the final 3D model. Indeed, this model was built to provide a reference and an interface to an archaeological information system (AIS). In a second part, the paper shows how the same 3D model has been enriched by data and knowledge from different archaeological surveys. That way, the collected archaeological data, the structure of these data, the whole process of integration and finally the importance and contribution of the 3D model in the process of site understanding are analyzed. The archaeological record consists mainly of field surveys and interpretive reports of the excavations. The geometric data come from the transcription of field observations in form of cross sections. These sections were then digitized. Thanks to the combination of geographic information (positions and elevations) contained in the documentation and the accuracy of the 3D model, they could be georeferenced and incorporated into the model. Stratigraphic layers were decomposed into geometric shapes and structured according to the needs and habits of the various archaeologists who worked on the site: thus, an original and specific workflow has been developed. Disparities in the working methods of different archaeologists have been confronted but yet integrated into a single environment, in a homogeneous way, through the use of the 3D model as a single repository. Again the 3D model has led to improvements in the homogenization of collected data. Non-geometric knowledge was structured, recorded into a database and linked to the geometrical model. The 3D model can now act as an interface and Archaeological Knowledge Information System (AKIS) combining the assumptions, interpretations and representations of the castle over several centuries. The addition of a time slider in the AKIS allows to view the developments on the site over the time. This represents a fabulous tool for archaeologists and historians. The accurate 3D model and the associated geometric analysis tools included in the AKIS have notably allowed to identify several unsuspected parts that were completely covered with vegetation, as spread remnants of the main emblematic and destroyed tower. The implemented system for the knowledge dissemination and analysis of the site was completed by another approach that is presented in the third part of this paper. It consists in a virtual tour of the site. The creation of the virtual tour in form of panoramic views is now well known. But besides the interesting interactivity, the addition of structured information as links to external documentation allows here again to enrich this visualization interface.

This study has finally allowed to identify the specific contributions of a 3D model and its derivatives in an archaeological analysis. Eventually, the paper discusses the limits of existing material in 2D and describes the development of a modeling process and the transition from 2D to 3D, as well as it discusses the emerging problematic related thereto.

1. INTRODUCTION

The paper describes the implementation of a 3D model of the Engelbourg castle in Thann, Alsace, France. This castle from the 13th century is now only standing in a state of ruins. Indeed, the situation in eagle's nest overlooking one of the major crossings between Alsace and Lorraine, that is to say the precise reason for its founding, was the cause of its systematic destruction in 1673.

During the last years, these ruins have been the subject of several thorough archaeological studies. They now constitute a very rich documentary base. The LSIT/TRIO team has been modeling the ruins and its surrounding environment for two years, using surveying, photogrammetry and TLS techniques. The model of the current state was formed with an important quality and geometric accuracy. This task is one of the main objectives for the 3D model. It is a benchmark dataset in the development of a Archaeological Information System, using techniques that are still undeveloped in the archaeological field and away from traditional methods. This project allows to study the integration of 2D data from various archaeological sources, making a comparison of conventional methods used at an interval of twenty years. 2D data used for this study are those of the archaeologist Ehretsmann [1], which launched a campaign of excavations at the site in 1992 and drafted a report with different cross sections drawn from it surveys. Today J. Koch, a member of PAIR (Pôle Archéologique Interdépartemental Rhénan), who is in charge of archaeological survey of the site and whose recent excavations are also to be integrated into the 3D model.

The first part of this paper describes the different stages of a classic archaeological survey, the methodological approaches that are used and the latest technologies that are applied in this field. The 3D modeling process of the site will be developed in the second part and then we'll see how to integrate the 2D data into 3D model. Finally, we conclude on the contribution of these methods and the changes that the laser scanning (TLS) and 3D modeling can operate on archaeological approaches.

2. ARCHAEOLOGICAL METHODS

2.1 State of the art

To understand the evolution of methods used in archeology, we must examine the major stages of work that are exploration, excavation, conservation, data management, and finally, restoration and dissemination of data. [2] describes the archaeological information as a historical document and unwritten history, highlighted by the excavations and the findings of the archaeologist.

Prospecting is one of the first steps of recognition of a site as a quick read for identifying the most relevant parts and rewarding site to study. It can be done in different ways, depending on the terrain and the accuracy of research, but should not be destructive of the site. [3] gives two main areas of exploration in differentiating observation (visible surfaces, traces of various kinds, etc.) and ground introspection (use of remote sensors for example). Conventionally, the observation is done by walking on the site, but since the 1960s, aerial photography applied to archeology allows a broader view of sites to explore, as well as identifying areas of interest. J. Dassier, one of the first French air prospectors, explains this technique and presents his work on his website [4]. For example it is possible to discern areas built in the basement due to differential maturation of cereals that causes a touch of color visible from the sky. Aerial and terrestrial photogrammetry is now a science widely used in the field of archeology, and tends to grow further with the advent of TLS surveys. Ground introspection, another method of observation, uses the physical properties of the observed field, of the basement or of the parts not visible from the ground, and may be of different nature: geophysical, electrical, magnetic, etc. [5].

Second stage in the archaeological process before excavations consists in soundings. They can be likened to a method of exploration, because they serve to delimit an area of excavation, but like the excavation it is a destructive process that allows to confirm or not an assumption made by external observations.

[6] distinguishes three types of surveys:

- Staggered soundings: they are discontinuous rows of sliced, more or less long, and arranged one beside the other,
- Sliced continuous soundings: they are sliced strips of continuous, arranged one beside the other,
- Cores with longitudinal profiles: they are regularly spaced core holes and made in grid.

After this stage, archaeological excavations can highlight buried items or overlaying geologic strata. Here there are several methods, or more precisely several categories of excavations:

- Stratigraphic excavation: vertical excavation for dating events and tracing the history of the land by studying the various geological formations and archaeological remains belonging to them. Stratigraphic excavation is based on the stratigraphic unit defined as the smallest subdivision of a stratigraphic sequence data. This process follows two fundamental laws of geology that is the law of continuity and the law of superposition. According to the law of continuity, each stratum is bounded at its base and its top by a pool of deposit. According to the law of superposition, the deeper layers are older than those that cover them. The analysis of the interaction between the layers is one of the main objectives of stratigraphic excavation, which is essential to understand the historical site. In order to better visualize the layers and their links, archaeologists rely on the matrix of Harris, which allows a simple and schematic representation of the actual representation:
- Open air excavations: horizontal excavation, generally shallow, with the aim to visualize the spatial distribution of surface elements. It consists of a stripping of topsoil, until the appearance of the first layer, then the excavation for restricted areas (usually squares, side by side or not) [7].
- Combination of vertical and horizontal excavations: the method of Wheeler [8] is defined by a horizontal division into zones and at each zone a stratigraphic excavation is conducted, more or less deep, and whose highest level is marked by berms.

The stage of excavation would not be so critical if the information coming to light were not recorded, even if during the excavation, the finds are destroyed. For [9], paper sketch and photography are two techniques for registration of the additional archaeological data. The design involves the proper interpretation of the archaeologist and his talent as an artist but it follows some rules of representation: for example, the line width has to be greater for items that are in the foreground, or a dashed delineation is required for the outline of excavations. The design also gives the opportunity to focus on areas chosen to bring out important details that are difficult to distinguish and to sketch what does not require high accuracy.

It is essential to represent the designed element with good proportions, and locate it in a coordinate x, y, z , so that you can find out later the relationship between the remains identified. From an origin point $0,0,0$, other points are determined in a local reference. In addition to drawing, photography can freeze the reality of the site during the progress of excavations. It is possible to record the remains in their broadest context, and more objectively than a drawing it is a way to account [10].

Used since the 19th century by the Egyptologist R. Lepsius during excavations in Egypt, while this technique was developed until some years ago [11], photography and its rapid evolution play an important role in the methods of archaeological excavations. Digital images have the advantage of being easily stored on a computer system and provide very good resolution. The digital processing options such as color enhancement, cropping, etc. also promotes the use of data for advanced visual analysis. [6], distinguishes documentary photographs, which must contain a scale, are used for presentation and analysis from illustrative photographs, usually used for publication. The recording of visual data of excavation is a key step for the archaeological study but it is only part of a set of normalized information. It is then completed over analysis, identifying, inventorying and classifying of the remains collected.

The protocols for recording and marking generally follow the same logic of inventory and marking, assigning to each element, an identifier, the name of the site to which it belongs, the location of the site, chemicals, etc. But it nevertheless up to each agency to follow its own procedures, adapted to its internal organization, and although many papers and articles have been written in order to establish general rules for recording archaeological data, many have adopted an own database structure and an inflexible methodology. It is nonetheless an obstacle to cross-check information among various agencies and excavations. It checks homogeneous distribution of data. Many valuable elements are well archived in a more or less permanent artifacts library and lose part of their potential of information.

In 2008, the French Ministry of Culture and Communication [12] distributed to agencies responsible for public collections marking a methodological guide for product evaluation and labeling methods designed to create uniform practices for the marking of public collections. This guide was born after several test programs of LNE laboratory (National Laboratory of Metrology and Testing) and Research Center for French Museums (C2RMF). It was not easily adoptable for many archaeologists, as very general and sometimes not conforming to standards actually applied. Finally, the development of computer tools such as

GIS and transmission of information via the Internet grows to move increasingly towards collaborative and shared standards. This was demonstrated in the work of [13] which raises the possibility of establishing an Archaeological Information System (AIS) accessible to all professionals to integrate their databases and share them seamlessly and exploitably.

Until the 1980s, early commercialization of the first information systems, data recording was done manually and is listed in the paper sheets. More and more computer provides itself as a solution beneficial to all levels of the archaeological field, in collecting information, publishing, through analysis and record keeping. For archaeological design, a wide choice of software exists now, such as Adobe Illustrator for creating vector graphics, image scanning or digitizing images. These new tools commonly used today have the advantage of saving time for making the drawings, a gain in accuracy and realism. Digitizing of raster data is particularly useful for the map realization, the digital reproduction of photographs or drawings made in the field, based on the layer principle. But they also allow the integration of old data, which encourages archaeologists to reopen files, sometimes neglected, for further analysis. In our study, the Ehretsmann's cross sections are intended to be digitized and integrated into the 3D model. These developments coupled with the advent of tools for creating and managing database, bring a new way of thinking about the archaeological information.

2.2 Archaeological Information System

Information systems are based on databases concepts in which tables with fields are joined together. Defining tables and fields they contain remains complex because it is necessary to fully understand the interdependencies that bind all the elements (geographical area, chemical composition, time, location, etc.). Partly for this reason it is difficult to establish a single system. Each archaeologist has its vision of logical data structure. The preliminary study on the establishment of an information system should enable the development of a conceptual data model. Nowadays, the establishment of archaeological databases have become almost ordinary for many groups of archaeologists. Standards were also established to allow a common description of archaeological objects and metadata to provide data descriptions for different users.

A system called "AsSol" [14] was designed to manage the field data and facilitate the excavation and post-excavation operation. It permits the transfer of information to other systems, including geographic information systems. This example illustrates the potential of tools dedicated to managing and sharing of archaeological work, even if these databases are still relatively local and heterogeneous.

The computer became also, beyond the sharing and standardization of information, a means of enhancing and disseminating the results of excavations. Restitution is now requesting archaeological virtual digital technologies such as CAD design, but also the creation of 3D models [15]. With the help of electronic data acquisition (total stations, 3D scanner), it is possible to scan entire archaeological sites and relics of almost any kind of the model to have a realistic and whole visualization, and also manipulate the models to perform simulations and treatments [16]. The modeling allows entirely new behavior and mechanisms analyzes. The simulation elements, parts of which have disappeared is also an invaluable tool.

These techniques are still new and all the archaeologists are not able to address. Many projects are developed modeling by private companies, but more and more accessible software and open source are dedicated to this type of application. 3D modeling is the subject of the next part of this paper.

3. 3D MODEL OF ARCHAEOLOGICAL SITE

3.1 Fieldworks

The fieldwork was done in three main parts: i/ the establishment of network of reference points for automatic point clouds georeferencing, ii/ the various TLS point cloud acquisitions and finally iii/ the shooting of images to perform the panoramic virtual tour.

3.2. TLS Acquisition

The point clouds were recorded with a "Trimble GX" TLS. The characteristics of the scanners are given in [17]. The 3D scanner "Trimble GX" has characteristics that were optimal for the type of survey conducted. But its performance in speed of acquisition are now largely outdated. Direct georeferencing was made thanks

to the reference points measured in the first step. The mean accuracy obtained after setting up scanner station was +/- 1 cm. The parameters of "Trimble GX" were set to acquire point clouds with a spatial resolution of about one centimeter at 20 meters. Scanners stations were chosen to cover the entire site. The TLS work consists in 37 scanner station, the measuring of 52 objects and 5 360° scenes for a total of 35 million of points and a scanning time of 8 hours and 56 minutes. Figure 1 gives an overview of the combination of all the point clouds during the various campaigns.



Figure 1: combination of all point clouds

3.3. Photogrammetric Surveys

The equipment used for image capture was composed of a digital camera *Canon EOS 5D* type *SLR*, a digital camera *Sony Bridge H50* and a tripod. Images were taken to model detail part of the Engelbourg's ruins. The *PhotoModeler* software was used to model and texture the 3D model.

3.4. Panoramic Image Capture

The material used for the panoramic shots was a camera *Canon EOS 5D*, type *SLR*, a spherical panoramic head *Manfrotto 303+* and a tripod. During the study, a new opportunity that was not originally planned to describe the ruins was tested: the virtual tour from panoramic photographs. The formation of an assembled panoramic photograph requires a large number of photos using a spherical panorama head. In general we must ensure an overlap between photographs of about 30 % minimum and we cannot use photographs with too pronounced contrasts differences. The assembly and photo rectification was performed on the *Autopano Giga* software. The positions of different points of view were chosen according to ensure the inter-visibility between adjacent positions. By following these criteria, the virtual tour created allows the user to move from one point of view to another one, as he would do naturally in the real world. Each picture was taken with a gap of 24° horizontally with approximately 50 % overlap and with a lens focal length of 24 mm. That means 15 photos to cover 360°. A complete panoramic photograph requires in this case 5 series of 15 photographs taken with vertical angles of -30°, 0°, +30° and +60°, then one last image at +90°. This brings us to a total of 61 photographs. The Figure 2 shows a panoramic image of the "Eye of the Witch", characteristic view of the ruins.

3.5. Modeling

The aim of the study is to provide an interactive 3D model which content can be integrated in an interactive terminal. This 3D model will allow the public to visualize the ruins, manipulate the model and explore the site. It will also supply professionals, experts, historians and archaeologists with an accurate 3D model that could be taken as reference.

The unrefined point clouds cannot be directly used for this application. Therefore, from the data it provides, we have to create a workable model. The software used for the establishment of this model is the *Google SketchUp* [18] package.



Figure 2: panoramic view from virtual tour of the Engelbourg's ruins

3.6. Structuring the model

The model is structured in layers and coded color. Each sector is numbered and identified according to its position and function as the description given by Ehretsmann. Identification is then used to associate any type of data in digital form (drawing, photography, mode of assembly, drawing, collecting descriptive report, hyperlink to web page, etc) to each constitutive element of the ruins.

This structure is very important for the case of model integration into an Archaeological Knowledge Information System (AKIS) especially in 3D-AKIS. The analysis capabilities of 3D-AKIS combined with a high performing documentation management system was used here to provide a tool for archiving and documentation, allowing full analysis of the complex structure.

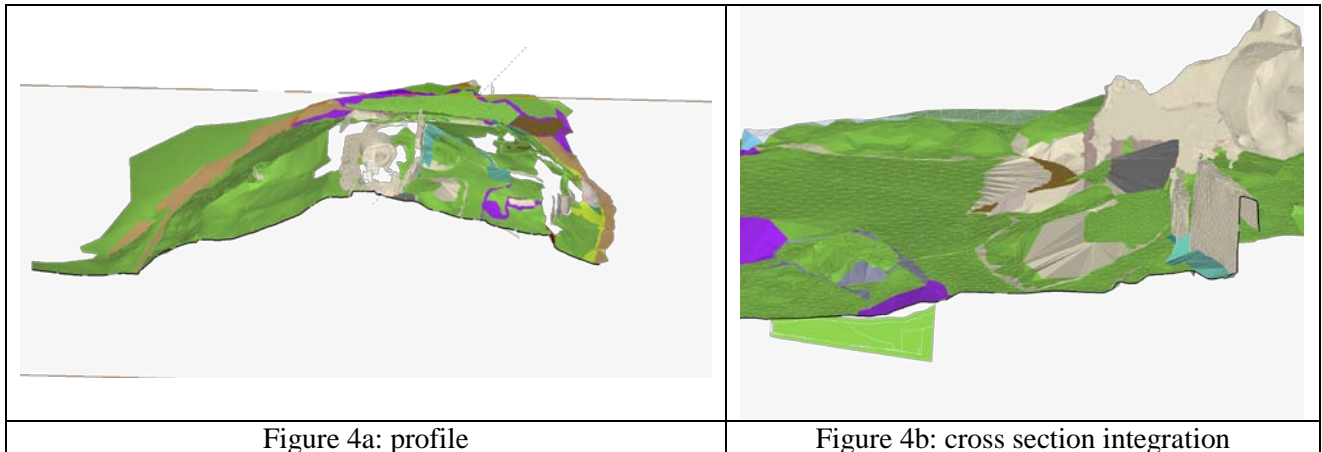
4. FROM 3D MODEL TO ARCHAEOLOGICAL KNOWLEDGE INFORMATION SYSTEM

The cross sections on which the archaeological study bears were identified by Ehretsmann who in 1992 conducted a campaign of excavations at the site of the Engelbourg at the request of the town of Thann, Alsace, France. He brought together all his drawings, plans, observations and analysis in a survey report. The goal of the visualization of the cross sections in the 3D model is firstly to obtain a comprehensive view of all the Ehretsmann's excavations, then to enrich the model considered as a real database and finally allow archaeologists to overlap with 3D information different analysis of the site.

The cross sections were first scanned and stored as images in PDF format. They are then automatically digitized by using the *ArcScan* module of *ESRI's ArcGIS*. As this study takes the perspective of the establishment of a GIS of ruins and the development of the site, it is important to segment the digitizing of distinct elements to associate them with additional descriptive information. Blocks were created with the remarkable strata thus defining facets (Figures 3).

<p>Figure 3a: original cross section</p>	<p>b: block n°7 extraction</p>	<p>c: digitized cross section</p>	<p>3d: geo-referenced cross section with outline</p>

To comply with the representation of the contours of excavation, a particular line is created defining the section at the underground level. The blocks and the outlines are transferred to shapefile, and exported from *ArcCatalog* into DXF format. There are then imported in *AutoCAD* to be georeferenced. Indeed, the vectors created from the image are flat and not referenced. In *AutoCAD* the 3D points determined by a surveyor are assigned to the two ends of the cross section. The section (block and outline) is then aligned with respect to such matters. It is then possible to re-import the georeferenced section in the *Google SketchUp*. After registration as a SKP file format, the section can now be incorporated into the final model. The Figures 4 shows the results of the integration of archaeological sections of this study.



5. CONCLUSION - CONTRIBUTION OF THE 3D MODEL TO ARCHAEOLOGIE

The contributions of 3D modeling in the study of the Engelbourg's ruins are numerous and can be extended to the field of archaeological heritage in general. We can distinguish three main levels of contribution which are tourism, development and scientific research.

At first, the representation of the site in three dimensions allows a very credible rendering, especially through the application of realistic textures and adding of elements such as vegetation, for example. It is then a considerable asset for tourism and culture, as it allows to discover the heritage, as can be observed for those who currently have no opportunity to visit the site. For the youngest to the oldest, access to archaeological information becomes easy, understandable and even fun. In addition to written information, 3D models provide a first, fast and universal visual reading. It is also interesting to show the public the evolution of the site, or simply digitally restored remains thanks to 3D simulations. This exempts from treading the ground and touching the artifacts which could distort or damage the data.

Providing a virtual 3D model could be considered as a valuable aid for development proposals on archaeological sites. Indeed, knowledge of the soil in three dimensions gives a good idea of the topography of the site, more representative than the maps. The model simulates the desired layout and provides opportunities for creation and modifications; this becomes more tedious when working on real models. The structures can be placed in a much more extensive environment than for a manually made model, which is, to keep a suitable scale, limited in size. The level of detail and highly developed ability to manipulate the virtual object (rotation, zoom, decomposition, assembly, etc.) allow to observe it with more fun and much closer than if it was standing still and behind a showcase. More generally, the 3D model proves to be a very appropriate means of communication to attract and persuade visitors. It also gives an interactive view of the site in addition to written descriptions and photographs of the scene.

Just as it is difficult to observe with the same level of detailed elements of the center of a real model (which are inaccessible and sometimes hidden by other elements), it is sometimes necessary to make several models of different scales or cut into cross sections in order to distinguish all the essentials. These constraints do not apply to 3D models as all levels of scale are available through the interactive zoom. Sections and profiles are easily achievable. Display and navigation options can observe every part of the model from all desired points of view. Beyond the simple visual aspect, developers have access to soil composition and know where the remains and protected areas are located. This prevents accidentally damaging valuable material for lack of information on the location, at work, and allows management to adapt to the constitution of the basement.

Others directly affected by the virtual visualization tools of archaeological data are the archaeologists themselves, because in addition to artistic attractions new opportunities appear in archaeological analysis with 3D models. Indeed, the overall pattern provides a clear vision of the site structure and the location of elements (artifacts, layers, sections of excavations, buildings, etc.). It is thus easier to appropriate the field, to analyze the contours, to read and to locate the excavation. Overlaps and links between data are very obvious, because readily available and comparable. The same applies to certain assumptions, sometimes long to verify, or left out for lack of elements and time. These tools allow borrowing thinking paths that were not dealt with the only 2D documents and the artifacts collected and archived in the laboratory. It is possible to locate in the 3D model each discovery, to simulate scenarios and the relevance of the analysis results in a gain of precious time. Although the contribution of 3D model has no fundamental impact on survey methods, it operates some change in the design of data recording and analysis. Being able to push the frontiers of research by bringing together on a single model, data generation, geographic locations, links *a priori* very far, in some way promotes data standardization and establishment of universal, as broadest as possible databases, when the 3D model will serve as a hub of knowledge.

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7. REFERENCES

- [1] M. Ehretsmann [1992], Rapport de fouilles programmées : Engelbourg, DRAC Alsace, 159 pages.
- [2] F. Journot and G. Bellan [2011], Archéologie de la France moderne et contemporaine, Editions La Découverte, ISBN 978-2-707-15940-3, 180 pages.
- [3] A. Guyot [2005]. *Les méthodes de prospection, l'archéologie en chantier*.
<http://www.diffusion.ens.fr/archeo/tech/atfolder.2010-07-07.4415005383/folder.2005-04-15.8099363532/>
- [4] Archaero [2007]. *Archéologie aérienne*. URL : <http://archaero.com/>
- [5] Archaero [2011]. *Archéologie d'Orient et d'Occident et textes anciens (AOROC)*.
<http://www.archeo.ens.fr/>
- [6] F. Giligny [2006], *Méthodes de l'archéologie*, Université de Paris 1 – UFR d'Histoire de l'Art et d'Archéologie, Licence d'archéologie, 2^{ème} année.
- [7] R. Miller [2005], *Techniques de fouille*, Université de Liège.
- [8] P. Courbin [1971], *Nouvelles méthodes de fouilles : le système Wheeler*, Archéologia n°38, ISSN : 0570-6270, 44 pages.
- [9] F. Ligny *et al.* [2004], *Le dessin archéologique, Méthodes et initiations d'histoire et d'archéologie*. Editions du temps, Nantes. ISBN 2-84274-290-7. Pages 191-194.
- [10] P. Racinet *et al.* [2004], *Photographie et archéologie, Méthodes et initiations d'histoire et d'archéologie*. Editions du temps, Nantes. ISBN 2-84274-290-7. Pages 200-208.
- [11] G. Feyler [1987], *Contribution à l'histoire des origines de la photographie archéologique : 1839 – 1880, Mélanges de l'Ecole française de Rome*. Antiquité. Volume 99. Page 66 sur 1047.
- [12] Ministère de la Culture et de la Communication [2008], *Marquage des collections publiques guide méthodologique : évaluation des produits et procédés de marquage*. 50 pages.
- [13] E. Meyer [2007], *Acquisition 3D, documentation et restitution en archéologie, Proposition d'un modèle de Système d'Information dédié au patrimoine*. PhD thesis, Centre de recherche en Architecture et Ingénierie – CRAI. 322 pages.
- [14] H. Galinié *et al.* [2005], *ARSOL, La chaîne de gestion des données de fouilles du Laboratoire Archéologique et Territoires*, Les petits cahiers d'Anatole, n°17, mai 2005.
- [15] J. Santacana, I. Mestre and M. Carme Belarte Franco [2005]. *Idées et débats de la restitution en archéologie, Problèmes généraux concernant la restitution en archéologie*. Centre des Monuments Nationaux, Editions du Patrimoine. Pages 6-10.
- [16] Q. Borderie et G. Subsol [2010], *3D et archéologie*, ATER Université de Paris 1 et CNRS Montpellier.
- [17] GIM International. (2010). *Product survey compare, Terrestrial Laser Scanners*, august 2010.
- [18] Google Sketchup, (2010). 3D modeling for everyone. <http://sketchup.google.com/intl/uk/>
- [19] J. Burnouf *et al.* [2009], *Manuel d'archéologie médiévale et moderne*. Editions Armand Colin, Paris. ISBN 978-2-200-35455-8.