CAA
2017

http://dx.doi.org/10.15496/publikation-43145

3D Digital Modelling and Digital History: A Methodology for Studying the Processes of Transformation of Nubian Temples and Landscape at the Lake Nasser Site

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Abstract

3D models are not only visualization and dissemination outcomes, but can be used to digitally collect, organize and visualize data starting from heterogeneous historical documents. In particular in this research 3D models are conceived to study the transformations of the sites along the river Nile now submerged by the Lake Nasser and the salvage of the temples. This paper illustrates the preliminary results and the issues about the use of 3D digital models to study the landscape and the temples before and after the construction of the Big Aswan Dam. The first results show that the discrepancy between the homogeneity of data required to build the 3D model and the non-homogeneity of historical documents is at the same time the weakness and the strength of the method, since it forces to explore new hypothesis and a proper use of paradata to manage the reliability of historical data.

Keywords: 3D modelling, 3D digital landscape, Nubian temples, digital history

Introduction

Models are one of the principal instruments of modern science (e.g., Frigg and Hartmann 2012). Among the different types of models used in science, the 3D models commonly used in architectural studies belong to the type of models based on analogy (Hesse 1966). 3D digital models are particularly powerful tools for the study and comprehension of historical sites and buildings, because, as underlined by Maldonado (1992), digital models allow a richer and more controlled interaction between user and model.

For this reason, 3D digital models, and the creation process of such models, are useful tools in the field of digital history. Historical research can be represented in a digital environment by visualizing relationships between buildings and sites, landscape details and changes. 3D models and virtual reality are commonly used to investigate the state of a building but can also be powerful tools to illustrate historical processes, a fundamental focus of digital history. The science of representation is of fundamental importance in achieving this as stated by Simon (1969) many years ago. The notion of substituting a process description for a state description of nature has played a central role in the development of modern science, and the description of a complex structure requires the right representation. 3D digital models are useful tools not only for state description but also for process description, in order to investigate how a historical building or site was conceived, used, modified, ruined or rebuilt; in other words, the physical and cultural phenomena that have characterized its life.

This paper illustrates the first results and difficulties related to the use of 3D digital models to study the historic transformations of the sites along the Nile river in the 20th century, before and after they were submerged by the waters of Lake Nasser. The research is conducted within an ongoing project entitled Cultural Heritage in Context: Digital Technologies for Humanities, carried out by a multidisciplinary team from the Department of Architecture and Design of the Politecnico di Torino and from the Department of Near Eastern Languages and Cultures of the University of California, Los Angeles (UCLA). The long-term project aim as a whole is to explore the possibility of developing a 3D virtual reality environment to recreate the drowned cultural landscape of Egyptian Nubia. In particular the aim of the very first part of the project discussed in this paper is to investigate the feasibility - as well a suitable methodology - of creating digital models of buildings and sites from the available historical documents and maps. From a long-term perspective, this paper is addressed to scholars as a resource for further research, as well as a way to convey narratives about the changing landscape of this region. More specifically, the first part of the project outlined here is geared towards the instruction of architecture students. The project is based on integrated and multidisciplinary approaches in archaeology and cultural heritage, and on the use of digital data processing and management.

Overview

Between 1960 and 1980, the Egyptian Nubia, defined as the area of the Nile Valley between the first and second cataracts, was deeply transformed by the construction of the Aswan High Dam, the flooding of a huge part of the territory, and the displacement of the main temples during the international campaign carried out by UNESCO (Säve-Söderbergh 1992; Tamborrino and Wendrich 2017). The scale of flooding provoked by the construction of Aswan High Dam was unprecedented and was the cause of a huge environmental change in the Nile region with the creation of Lake Nasser. Because of the dam, a large territory changed forever. The age-old structure of the river Nile and the relations of the people in its valley were transformed by the lake that was created and by the people and monuments that had to be evacuated.

This was a multi-scalar disaster that can be analyzed using a multi-scalar process for studying and visualizing historical changes related to the event. Digital Humanities methodologies have created new perspectives for historical research. Documentation can be collected into digital datasets which allow for the management of a new quantity of data. Data can be spatialized and modeled in new ways, presenting all the information recorded in written texts, historical cartography, and iconographic sources in spatial-temporal settings, in order to recreate a new scenario of understanding. In the case of a catastrophe, how to represent historical research by visualizing the dynamics of change is especially relevant. This approach can allow the recreation in VR of the landscape before the catastrophe in order to recreate a rich framework of information for a better understanding of the relationships between the monuments and the context. It is particularly effective in the case of archaeological remains where 3D models allow the reconstruction of ancient fragments.

The possibility of effective use of 3D models is related to the reliability of the model. Such issues are addressed by the London Charter for the Computer-based Visualization of Cultural Heritage, that focuses on paradata to provide information on the human processes of understanding and interpretation of data objects. For this reason, the London Charter underlines the fundamental importance of the Documentation Process: documentation of the evaluative, analytical, deductive, interpretative and creative decisions made in the course of computer-based visualizations should be disseminated in such a way that the relationship between research sources, implicit knowledge, explicit reasoning, and visualization-based outcomes can be understood (Denard 2012). Some approaches have been developed over the last decade to disclose the knowledge and research claims made with virtual environments, such as the annotation system developed for VSim, a software prototype for interacting with 3D computer models in educational settings that we are using in this research (Snyder 2014).

Methodology

This paper focuses on the description of the methodology used to create 3D models of the landscape and temples starting from historical documents. This is part of a wider process that comprises the historical research involved in the UNESCO Campaign, the digital processing of historical data and the conceiving of a new storytelling format for the campaign; the whole process is described here in brief, in order to provide a useful background, while the whole project will be published upon its completion.

Figure 1. View of the 3D model of the site of Abu Simbel temple, before and after the displacement of the temple: on the left, the original site along the Nile, on the right, the new site on the shore of the Lake Nasser.

In this research, 3D models are used as a tool to collect, organize and visualize data starting from heterogeneous historical documents. 3D models are conceived and used to study the transformations of the landscape, including urban settlements and temples before and after the flooding following the construction of the Aswan High Dam.

The digital modelling activity aims to produce some computer-based outcomes:

- a 3D digital model of the portion of the Nile valley that was submerged by the flooding, before and after the disaster,
- digital models of all the temples that were saved by displacing them during the UNESCO campaign

Multidisciplinary Approach and Composition of the Research Team

Given the project's complexity, it requires a multidisciplinary approach. For this reason, the team is composed of researchers from different disciplines: the History of Architecture, Digital Modelling, Representation of Architecture, Egyptian Archaeology, and the Digital Humanities. In order to process the huge number of historical documents and to build the 3D models of all of the 15 temples saved in the UNESCO campaign, 70 students attending the Master of Science in Architecture for Heritage Preservation and Enhancement at the Politecnico di Torino were involved under the supervision of members of the research team.

Delimitation of the Study Area of the Case Study

The area of interest is the area along the river Nile that is now submerged by the waters of Lake Nasser, between the first and the second cataract of the Nile, and in particular between the Aswan Dam in the north and the temple of Abu Simbel in the south (Figure 1). The distance between the two sites is approximately 280 km measured following the course of the Nile. The area housed many 20th century villages, with thousands of buildings, that have been submerged, and 15 major Egyptian temples that were saved by relocating them to higher ground or to foreign countries.

The model of the terrain covers a surface which is approximately 4 km wide and runs symmetrically along the axis of the ancient River Nile before the flooding (the delimitation of the ancient river Nile is based on the survey carried out in 1959 before the construction of the Aswan High Dam). This surface follows the axis of the River Nile from the first Aswan Dam in the north to 20 km south-west of the site of Abu Simbel. In the case of the temples relocated to foreign countries, the new sites – museums or urban spaces - are modeled too.

Delimitation of the Time Range of Interestt

The research and consequently the modelling focus on the transformation of the landscape and of the cultural heritage due to the creation of Lake Nasser and the UNESCO Campaign for the salvage of the main temples of Nubia. The UNESCO campaign was launched in 1960 (UNESCO 1960) and was completed in the 1980s. For the temples that are near the Aswan dams, such as Philae (Figure 2), the time range needs to be extended because they were partially flooded as a consequence of the construction of the first Aswan Dam in 1902. As a result, and as a general rule, the digital modelling regards the construction of 3D models of buildings and sites ranging from the late 19th century to the late 20th century. In the case of some temples, if data are available and where they help understand the transformation process, 3D models of other and more ancient diachronic phases were also created.

Figure 2. Three frames of a video clip that shows a virtual reconstruction of the potential submersion of the temple of Philae due to the construction of the Aswan High Dam (3D digital model by Del Fabro M., Marchisio V. and Zanardo E.).

Input Data

3D models are developed starting from historical documents. Only in the case of the Temple of Ellesija, currently in the Egyptian Museum of Turin, was a photogrammetric survey carried out. The input data used for the construction of the 3D model of the terrain come from various historical cartographical sources, particularly the drafts of an aero-photogrammetric survey carried out in 1959 as part of a UNESCO campaign, on a scale of 1:10,000 (IGN 1959), and maps on a scale of 1:250,000 printed in 1958-1960 by the US Army.

The input data for the construction of the 3D models of the temples are very heterogeneous, with differing levels of reliability. These include descriptions and drawings by early travelers from the 18th and 19th centuries, surveys by architects, excavation reports published by archaeologists, topographical maps from the surveys done in the early 20th century, early photographs and films from the 1960s, and the documentation collected by UNESCO (Tamborrino and Wendrich 2017). As a consequence, according to the wealth of information and reliability of the historical documents, the level of detail of the digital models of every single temple is non-homogeneous and depends on the type of historical documents available.

Level of Detail

The digital modelling methodology is based on a multi-scalar approach: the level of detail, the scale of representation, the extent of the model, the content of the model, and the precision of modelling are optimized for every phase, as are the input data, the modelling software, and other digital tools.

The multi-scalar modelling methodology is based on three phases and levels, that correspond to three rising scales of representation, with the level of detail increasing from the first to the third level:

- Level 1 – territory: 3D modelling of the Nile Valley before the displacement of the temples;
- Level 2 – the building context: 3D modelling of the temples in their original context;
- Level 3 – building subsystems: building information models and/or more detailed 3D models of parts of the temples.

The result of these three levels of modelling is the creation of 2D and 3D content suitable for building a comprehensive multilayered model and multimedia products - animations and simulations - both for research and dissemination purposes.

Subdivision of the Modelling Process in Different Phases

The modelling process is subdivided into three main phases that correspond to the three levels of detail previously described.

Level/Phase 1: 3D Modelling of the Nile Valley before the Flooding | As mentioned above, the 3D model of the state of the Nile Valley before the flooding is based on various historical cartographical sources, particularly the drafts of the aero-photogrammetric survey carried out in 1959 and the maps printed in 1958-1960 by the US Army. The 1959 aero-photogrammetric survey covers an area measuring approximately 4 km wide, running symmetrically along the axis of the ancient River Nile before the flooding from Aswan in the north to 20 km southwest of the site of Abu Simbel. It is printed on 41

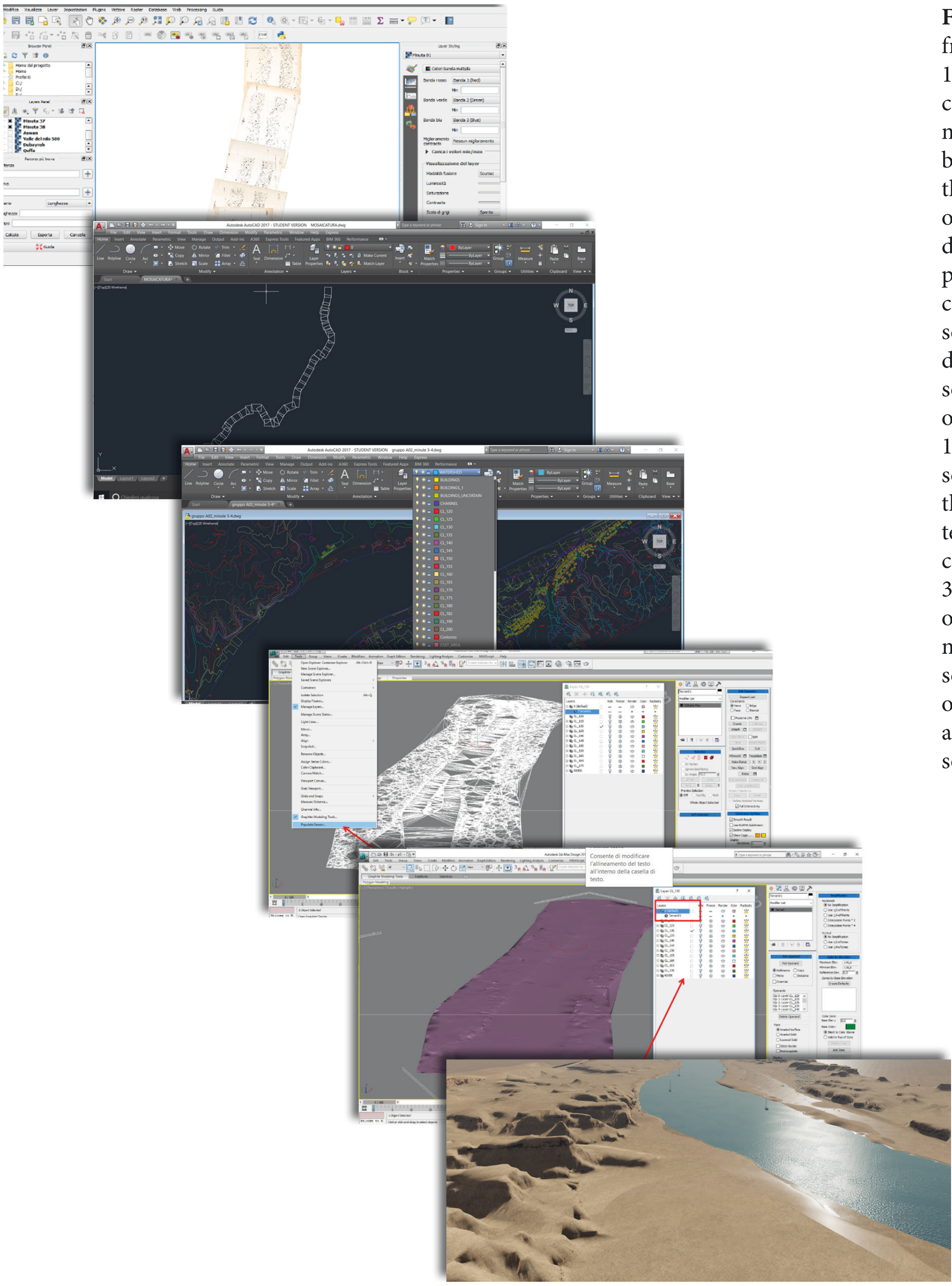

Figure 3. Screenshots from the Level/Phase 1 concerning the construction of the 3D model of the Nile Valley before the flooding. From the top: georeferencing of 41 sheets of the draft of the aero-photogrammetric survey carried out in 1959 (QGIS software); export for digitalization (AutoCAD software); digitalization of one of the 41 sheets of the 1959 survey (AutoCAD software); creation of the mesh surface of the terrain starting from contour lines (Autodesk 3DS Max software); optimization of a quad mesh (Populate Terrain software); refinement of the terrain model and rendering (Lumion software).

sheets, numbered starting from the south; but there is a small gap (a section measuring approximately 3.5 kilometers long) between sheet number 28 and sheet number 29. In the 1959 aero-photogrammetric survey, the topographic surface of the terrain below the elevation of 182 meters is described through elevation points and contour lines every 10 meters and some auxiliary contour lines every 5 meters. The portion of the map above the elevation of 182 meters, the area that was not to be flooded by the dam, is only described using contour points (with the exception of sheet number 21, where 10 m contour lines are used above the elevation of 182 meters) (Figure 3).

In order to produce the 3D model of the terrain, three tasks were performed. Task 1.1 involved the georeferencing of maps. This was done with open source QGIS software. The georeferenced maps were then exported into AutoCAD for the digitalization. Task 1.2 was the digitalization of maps. The digitalization was mainly carried out on the 1:10,000 scale

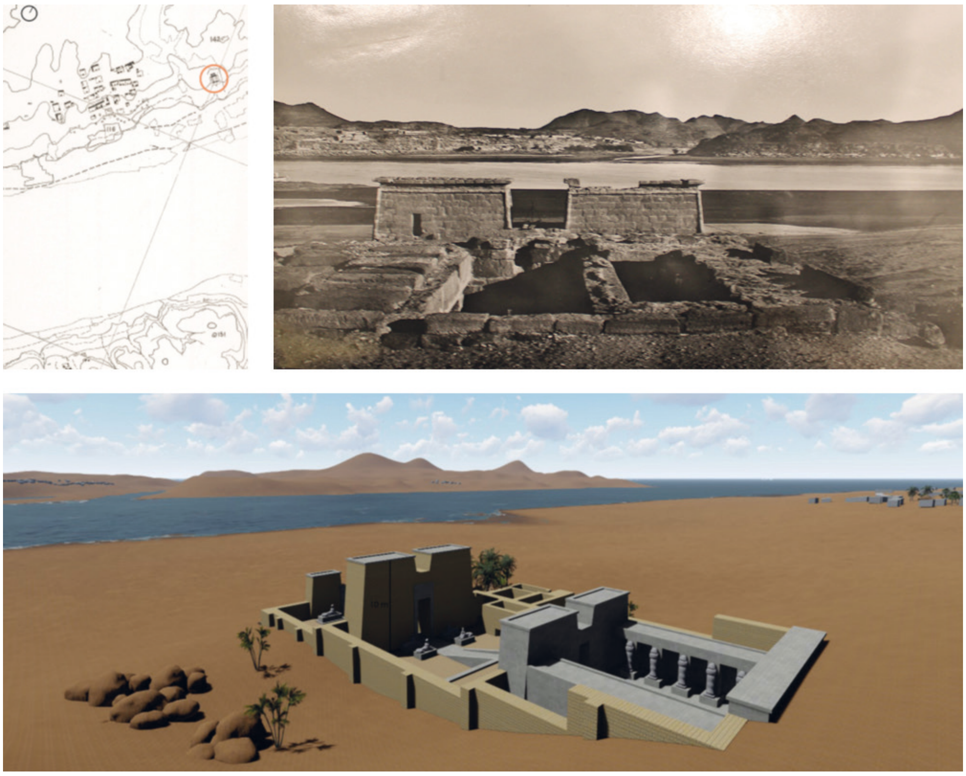

Figure 4. Identification of the original position of the temple and 3D reconstruction of the Temple of Wadi al Sebua and of the adjacent terrain features on the basis of maps and historical documents.

maps. We used the 1:250,000 maps to integrate the missing parts. The missing parts belong to three categories: the area between sheet numbers 28 and 29, the area between the ancient dam of 1902 and the new dam not covered by the 1959 survey, which corresponds to the area of the Temple of Philae, and the contour lines above the 182-meter elevation. The final task in this phase (Task 1.3) was the generation of the 3D surface of terrain based on contour lines. The generation of the mesh surface of the terrain is based on the digitalization of the contour lines. The surface of the terrain higher than 182 m above sea level that is missing in the 1959 survey was obtained starting from the contour lines of the US Army map (interval 50 meters) and from elevation points. The mesh surface is generated with the software Autodesk 3DStudioMax release 14 and the scripted plug-in Populate Terrain that allows the creation and optimization of a quad based surface that can later be remodeled using push-pull painting for example.

Level/Phase 2: 3D Modelling of the Temples in their Original Context before the Flooding | This phase was carried out in two tasks. The detection of the original position of temples on the scale 1:10,000 maps, when possible, consisted of Task 2.1 in Phase 2. The documents from Centre d'Étude et de Documentation sur l'Ancienne Égypte (or CEDAE) in our possession record the geographical position of every temple, in some case with great precision, and in other cases with less accuracy. For this reason in some cases this task was easy (for example the site of the Ellesija temple is precisely recorded), while in other cases the most precise information regarding the geographical position was the number of the map, and in such cases the detection of the exact original position of temples was carried out with a careful reading of the maps and other documents such as photos and paintings.

The second task (Task 2.2) consisted of creating the 3D preliminary models of the temples and of the adjacent contexts on the basis of maps and archival documents (Figure 4). The main elements of the modeled context are terrain, villages, and vegetation. The terrain model obtained in the previous task is refined using historical imagery where this exists (the quad based surface can be remodeled using push-pull painting for example). Currently the villages are modeled on the basis of the 1959 survey but only in the areas near the main temples, as a further procedural modelling of the villages constitutes a future task of the project.

A more detailed modeling of the temples is performed in task 3.2 (see below) and then imported

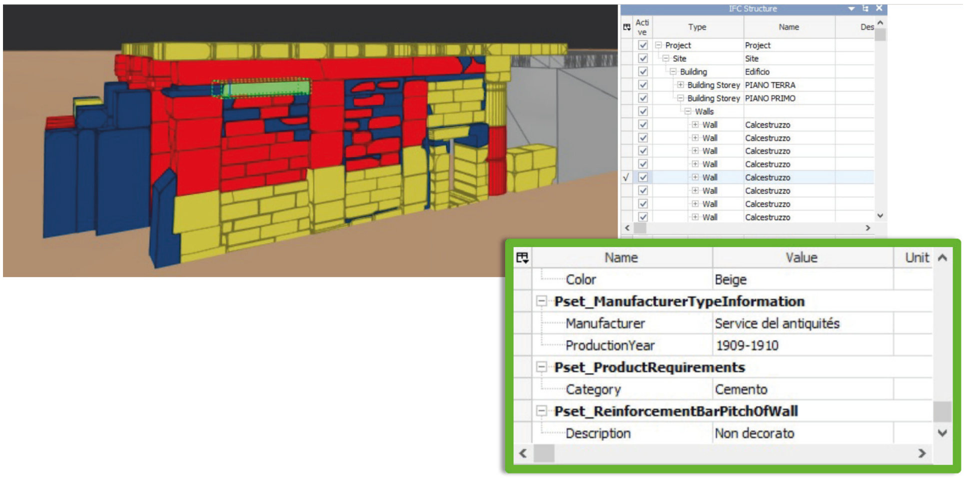

Figure 5. Building Information Modeling is used in order to associate additional information, such as alphanumeric data (e.g. date, material, state of degradation, management of restoration, etc.) or other files (e.g. images, archival documents, etc.) to building components. In this case, the BIM model of the Temple of Amada (Archicad 20 and IFC Viewer BIM Vision software).

into the model of the site. In this phase the input data are not homogeneous for all 15 temples, nor is the modelling strategy homogeneous. While the starting point is the same for all the temples, the terrain model created according to the UNESCO aero-photogrammetric survey, the refinement depends on the availability of the historical imagery, such as ancient photographs, paintings, or drawings. The modelling strategy for the site is approximately the same for all 15 temples: push/pull of the terrain grid, addition of textures, addition of vegetation features, addition of adjacent buildings, then rendering with the same Lumion software in order to ensure homogeneity of the rendering parameters. The reliability, however, is not homogeneous, due to many factors. The variable availability of historical imagery impacts reliability along with the fact some imagery, particularly paintings and drawings, is strongly affected by the subjectivity and cultural period of the author or artist. Historical illustrations often show different kinds of optical deformations in order to enhance some particular aspect of the building, such as the alteration of some perspective parameters to deliberately give the illusion of bigger buildings, as demonstrated in Figure 10 below. Last but not least, the interpretation of the historical imagery (such as the interpretation of the dimensions and distances of surrounding rocks) is affected by the subjectivity of the authors of the digital model, who are different for every one of the 15 temples.

Level/Phase 3: Detailed 3D Models of the Temples | This phase was carried out by completing two tasks. The 2D digital drawing according to historical documents and the scaling and digitalization of these archival documents comprised Task 3.1. As part of this task, the 2D digital drawings were overlaid on each other based on date in order to assess precision, reliability, and level of detail. The Level of Detail (LoD) is not homogeneous, according to the type and reliability of the historical documents.

Task 3.2 involved the detailed 3D modelling of the temple. 3D geometrical modelling was the standard method adopted to collect all the geometrical data from the historical documents; in some cases Building Information Modelling (BIM) was adopted in order to associate additional information, such as alphanumeric data (e.g. date, material, state of degradation, management of restoration, etc.) or other files (e.g. images, archival documents, etc.) to building components (Figure 5). The modelling strategy in this task is not homogeneous, as the input data, the nature and reliability of the historical imagery, and the features of the temples vary greatly. As a consequence, there was variability in the type of modelling, either geometrical model or BIM model, the level of detail, from modelling of the main features of the structure of the building only (basement, walls, doors, columns) to modelling the small details and building subsystems (decorations, constructive details, or even all the stones as unique elements), and the software employed, Autodesk 3DsMax and AutoCAD or Rhinoceros for geometric modelling or BIM Software (Autodesk Revit, Archicad).

Preliminary Results

The project is ongoing, but some preliminary results are evident. The first result is an original system of

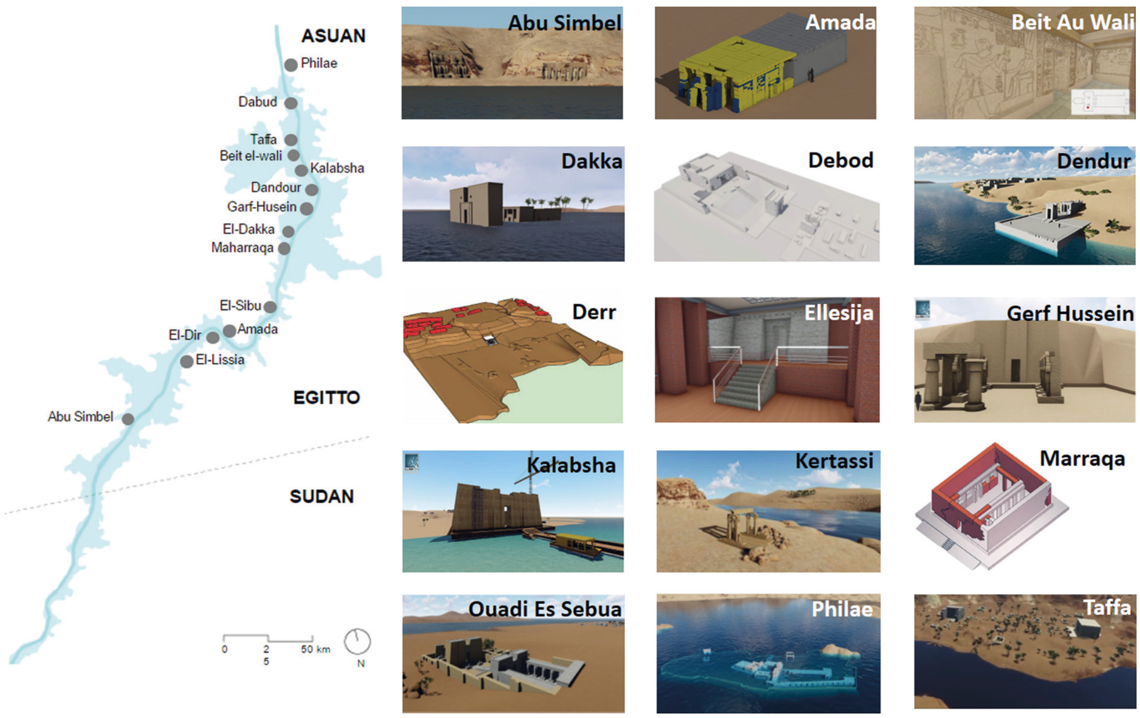

Figure 6. Cartographic elaboration of the area of the River Nile/Lake Nasser with the location of the 15 temples that were displaced, and a view of the model of each temple.

multi-scalar, 3D models of the Nubian area and temples. It is worth considering that, despite the existence of some systematic databases of 2D drawings (Fauerbach et al. 2010), before the start of the research project there was a great deal of uncertainty about the possibility of creating 3D models of every temple on the basis of archival documents only and about the level of detail obtainable for every site. That said, listed below are the preliminary digital tools, which will be improved in the second part of the project:

- 3D model of the terrain surface along the Nile, from Aswan to Abu Simbel, before the creation of Lake Nasser;
- 3D models of all 15 temples (building) and their sites (terrain, villages, and land cover) before and after the creation of Lake Nasser (Figure 6);
- a database of historic data, hypertext, and multimedia products – animations and simulations – of all 15 temples.

The importance of these preliminary results is as follows:

- the 3D model of the entire ancient valley of the Nile before the flooding is, as far as we know, attempted for the first time, and provides a homogeneous model of the 280 km long terrain surface;
- the models of the temples provide the first database of 3D models of all 15 temples. It is not completely homogeneous in terms of content and level of detail, but constitutes a strong starting point for further refinement and research;
- the digital models and the digital archive of historic documents constitute the basis for the creation of multimedia products – animations and simulations – of all 15 temples both for research and dissemination purposes.

3D models and the multimedia products are tools to improve knowledge in many ways, and in this project they are intended to improve our understanding of these buildings and their surrounding terrain as well the management of these places (Figures 7 and 8). As visualization tools, digital models and animations (through VR and videos) are commonly used

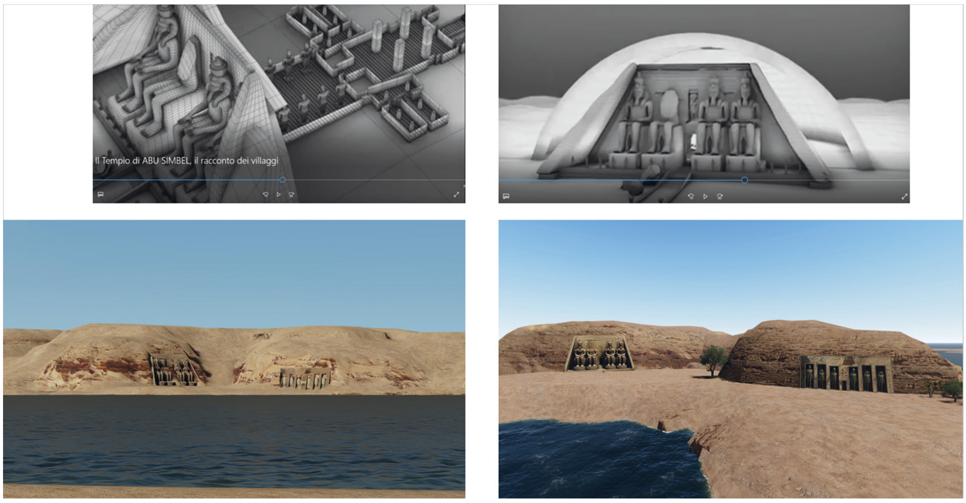

Figure 7. View of the structure and of the exterior of the temple of Abu Simbel before (on the left) and after (on the right) the displacement. The 3D model allows for views, such as exploded views or cutaways, that help the understanding of complex buildings, such as the temple carved in stone; the 3D model also allows the comparison of views of the temple in different diachronic states.

for dissemination purposes, because they constitute a user-friendly visualization tool for many categories of users (i.e. museums, web pages, and digital museums). In this project they are part of an educational program dedicated to architecture students in order to improve their understanding of aspects of the history of architecture. The results of the educational program (one or two videos and one or two hypertexts for every temple) will be revised in order to design further visualization tools to disseminate the final results of the research. A first test on a case study (temple of Dendur) was conducted with the prototype software VSim to develop an interactive and educational digital environment based on the 3D model, historical imagery, and videos (Figure 9). These 3D models are also being used to assess the reliability, precision or cultural background of sources. As a result, artefacts and distortions in historical paintings and engravings were discovered (Figure 10).

In terms of improving management, the use of Building Information Modelling allows the creation of models that can be enriched with information (see Figure 5). In this way the content of the model is not only geometric data but can be enriched with alphanumerical data, files, and links. The construction of BIM models was performed in some case studies (i.e., the temples of Amada and Gerf Hussein) when in possession of survey documentation with a good level of detail. A further application is going to be tested in a new project funded by Politecnico di Torino in collaboration with Museo Egizio di Torino.

3D Modelling as a System of Knowledge to Collect, Interpret, and Store Information

The first results show that the discrepancy between the homogeneity of data required to build the 3D model and the non-homogeneity of historical documents is both the weakness and the strength of the methods employed. This discrepancy forces researchers to explore new hypotheses and search new historic data, and forces students to understand and manage the reliability of historical documents. In conclusion, the research project aims to build an "open knowledge system of virtual models to study, manage, document, preserve, evaluate, and popularize cultural heritage linking the concept of representation to the concept of information and vice versa."

While our initial efforts have allowed us to create a digital environment for the visualization and study of the dramatic landscape transformations that resulted from the construction of the Aswan dam and the recovery strategies adopted to save the world heritage of the Nubian temples, future work is still necessary. In accordance with the Principles of Seville – an implementation of the London Charter in digital archaeology - the project underlines that "the environment, landscape or context associated with archaeological remains is as important as the ruin itself" (SEAV 2010). As a consequence of the strong connection between computer-based visualization and digital history, future work will be focused on materializing the principles of scientific transparency. To achieve scientific and academic rigor in this virtual

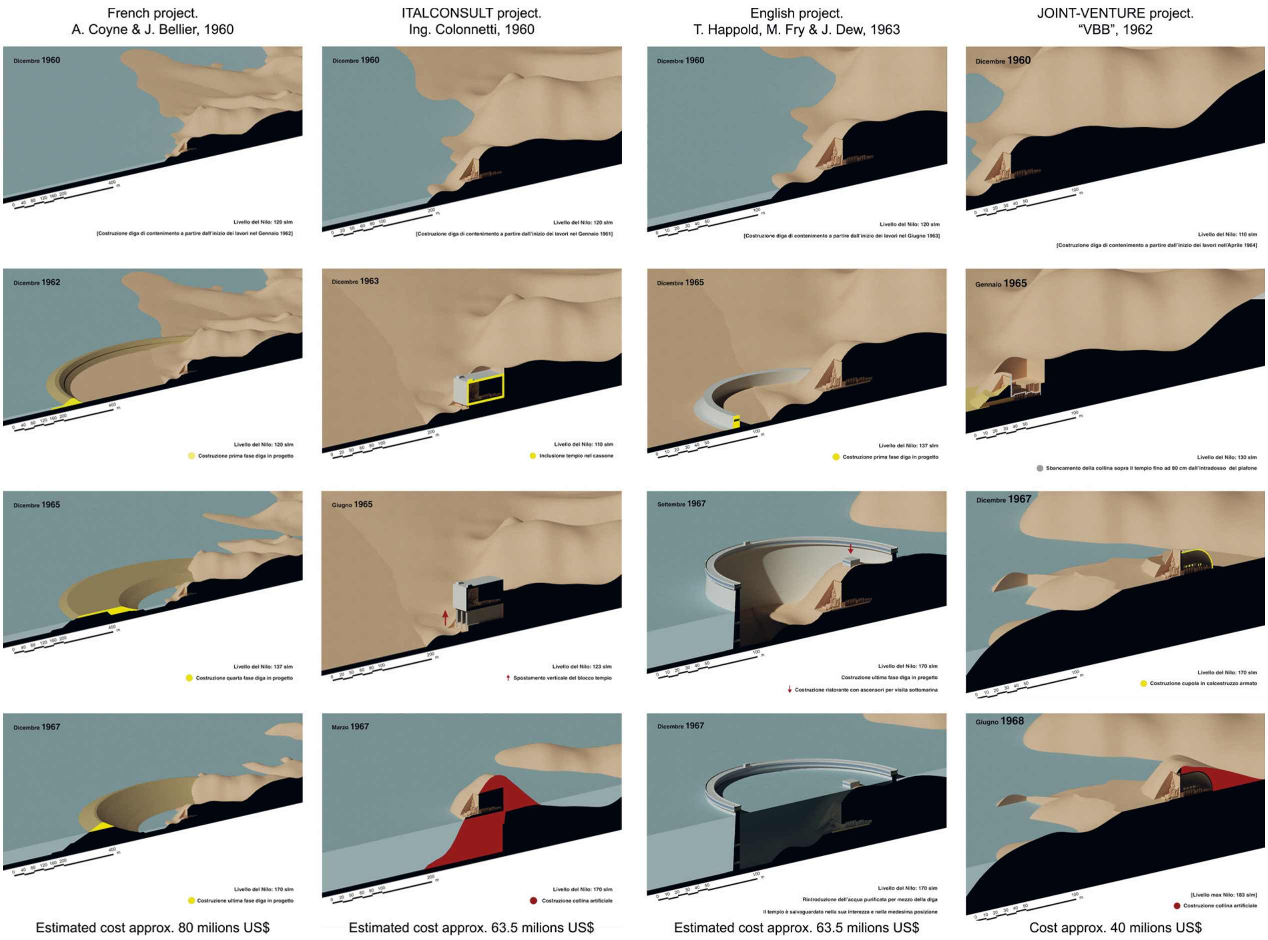

Figure 8. Graphic elaboration of the digital 3D reconstruction of four alternative projects for reducing the effects of the flooding in the case of the temple of Abu Simbel. Every column refers to a different design hypothesis, with progressive time phases. The reconstruction of digital 3D models allows the comparative visualization and study of the various alternative projects, by overcoming the graphical inhomogeneities of the historical documents. The comparative visualization is achieved by adopting homogeneous graphic standards: axonometric method of projection, identical relative position of plane and center of projection, congruent scale of reduction, similar level of detail, similar rendering lights and textures (3D models by P.E. Dalpiaz and G.M. Infortuna).

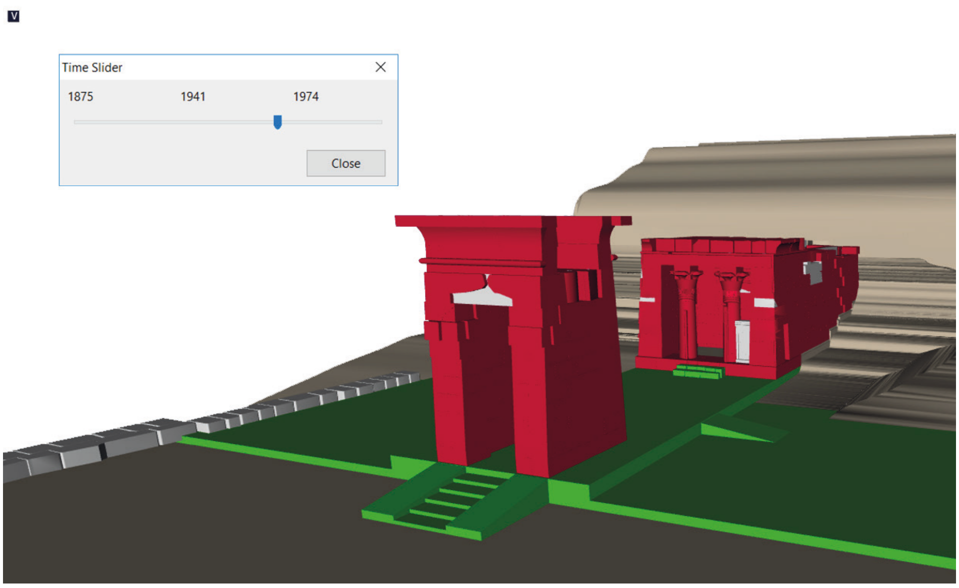

Figure 9. 3D model of the temple of Dendur in an interactive 3D environment with embedded resources, narratives and links to historical documents (software: Vsim prototype, under development at UCLA-IDRE (Institute for Digital Research and Education)).

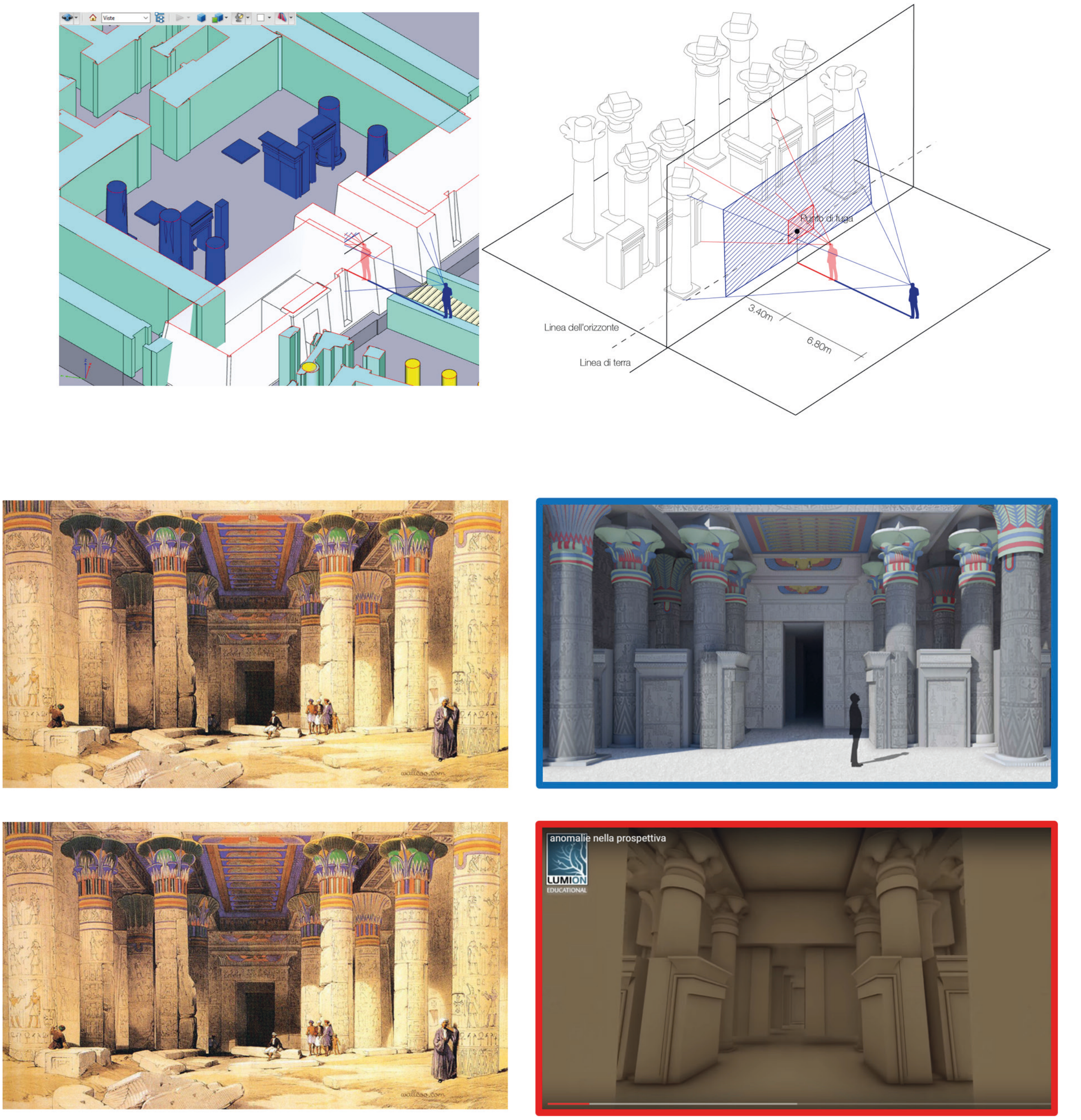

Figure 10. Example of use of 3D models to assess the reliability, precision or cultural background of sources. In this case, the 3D model is used to identify some perspective incongruences adopted by the painter David Roberts in this painting of the temple of Philae (1838) in order to emphasize the dimensions of the temple. The model is used in order to identify the point of view adopted in the painting (in blue), to verify that such point of view is not possible, as the view would be masked by the walls, and to compare the effect of the incorrect view with a plausible point of view (in red).

archaeology project, the intention is to prepare documentary bases to transparently present the entire work process: objectives, methodology, techniques, reasoning, origin, and characteristics of the sources of research, along with the project's results and conclusions. For this reason we are testing the adoption of software capable of incorporating metadata and paradata in 3D models (Procedural modelling for the villages, Building Information Modeling for the temples, Interactive 3D models with embedded resources such as hypertext and multimedia products and links to primary and secondary resources), as they are crucial to ensure scientific transparency.

Reference

Denard, H 2012 A New Introduction to the London Charter. In: Bentkowska-Kafel, A, Baker, D and Denard, H (eds) *Paradata and Transparency in Virtual Heritage*. Farnham: Ashgate.

Fauerbach, U, Wendrich, W, Khamis, S, Sählhof, M, Simpson, B, and Susak, A 2010 AEgArOn – Ancient Egyptian Architecture Online. In: Ioannides M, Fellner D, Georgopoulos A and Hadjimitsis D G (eds) *Digital Heritage. EuroMed 2010. Lecture Notes in Computer Science*, vol 6436. Berlin, Heidelberg: Springer, pp 463-472.

Frigg, R and Hartmann, S 2012 Models in Science, 25 June 2012. In: Zalta E N (ed.) *The Stanford Encyclopedia of Philosophy (Fall 2012 Edition)*. The Metaphysics Research Lab - Center for the Study of Language and Information - Stanford University, available at http://plato.stanford.edu/archives/fall2012/entries/models-science/ [Last accessed 04 August 2017]

Hesse, M B 1966 *Models and Analogies in Science*. Notre Dame, Indiana: University Notre Dame Press.

Institut Géographique National 1959 *Map of the Topographical Survey, scale 1:10.000*. Paris : Institut National de l'information Géographique et forestière.

Maldonado, T 1992 *Reale e virtuale*. Milano: Feltrinelli.

Säve-Söderbergh, T 1992 *Victoire En Nubie: La Campagne Internationale De Sauvegarde D'Abou Simbel, De Philae Et D'autres Trésors Culturels*. Paris: The United Nations Educational Scientific and Cultural Organization.

Simon, H A 1969 *The Sciences of the Artificial*. Cambridge, Massachusetts: MIT Press.

Snyder, L M 2014 VSim: Scholarly Annotations in Real-Time 3D Environments. In *DH-CASE II: Collaborative Annotations on Shared Environments: metadata, tools and techniques in the Digital Humanities*, Fort Collins: ACM.

Societat Espanola de Arqueologia Virtual 2010 Principles of Seville. Societat Espanola de Arqueologia Virtual, available at http://www.arqueologiavirtual.com/ [Last accessed 04 May 2017].

Tamborrino, R and Wendrich, W 2017 Cultural heritage in context: the temples of Nubia, digital technologies and the future of conservation, *Journal of the Institute of Conservation*, 40(2): pp168-182. DOI: 10.1080/19455224.2017.1321562.

United Nations Educational Scientific and Cultural Organization 1960 *The UNESCO Courier. Save the treasures of Nubia*, special issue February 1960 (13th year). Paris: The United Nations Educational Scientific and Cultural Organization.