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A Virtual Reconstruction of the Sun Temple of Niuserra: from Scans to ABIM

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Abstract
In 2010 an Italian team started new investigations in the Sun Temple of Niuserra (Cairo). The archaeological survey of the site was planned in order to re-examine the monument after its discovery in 1898. The work is mainly aimed at a general re-evaluation of the archaeological data still available on the site, in order to establish a new plan of the temple. More than 100 scans and several 3D models by digital photogrammetry have been acquired. In order to make all 3D data sets for different targets available, a Building Information Modelling (BIM) project has been developed. Thanks to this new approach, currently underdeveloped in archaeology, it is possible to produce categories of environmental and technological objects which represent the 3D semantic of the model. The paper deals with all the recent achievements, especially regarding the conceptualisation of the architectural model.

Keywords: BIM, 3D, virtual reconstruction, sun temple, Egypt

Introduction

In January 2010, an Italian archaeological mission started new investigations in the Sun Temple of Niuserra at Abu Ghurab, about 15km south of Cairo, Egypt (Figure 1). This monument, built by the sixth ruler of the fifth dynasty (about 2400 BC) in the royal necropolis of the time, is the first temple completely dedicated to the cult of the sun in ancient Egypt. Moreover, out of the six sun temples known from the historical sources, the temple of Niuserra is the only one which is still largely preserved and visible nowadays.

The importance of analysing this temple is thus clear, particularly when considering that the temple was first discovered by Ludwig Borchardt in 1898 (Borchardt, 1905) and, since then, it hasn't been investigated (Nuzzolo and Pirelli, 2010, 2011).

The state of preservation of the temple has also been dramatically deteriorating in recent years. This state of disrepair is astonishing when comparing the current ruins of the temple with the pictures from Borchardt's time. In most cases, in the latter pictures it is possible to see clearly some architectural elements of the temple which are no longer visible. For this reason, the archaeological investigation of the temple was aimed, first and foremost, at re-evaluating the archaeological data still available on the site in order to create a new plan and an architectural reconstruction of the temple.

The Sun Temple of Niuserra is a quite monumental complex, surrounded by an enclosure wall of about 110 m × 80 m and composed of the following parts (Figure 2):

- a central courtyard aligned with the main entrance;
- an alabaster altar for cult offerings and rituals in the centre of the courtyard;
- a corridor — originally roofed — which runs along three sides of the courtyard itself (northern, eastern and southern);
- a large area, in the northern side, occupied by warehouses and purification basins;
- a 'cult complex', in the southern side, composed of two contiguous rooms which are usually named 'Chapel' and 'Room of the Seasons';
- a truncated pyramid-like basement with a superimposed structure, usually called 'the obelisk', in the centre of the temple enclosure. The basement and the obelisk occupy an area of 1600 sq. m and are currently preserved up to a height of about 13 m.

Besides traditional archaeological methods and goals, however, the mission was also aimed at creating a 3D digital model of the temple, by means of laser scanning and digital photogrammetry (D'Andrea *et al.,* 2014). The construction of a 3D model and the acquisition of relevant data presents not only important technological aspects, but also gives us the possibility to compare the new survey with Borchardt's reconstruction provided in 1905. His reconstruction, however, presents many

Figure 1. The location of the Sun Temple of Niuserra on Google Earth.

inaccuracies, especially in concern with the shape of the central obelisk.

According to the German scholar, this part of the temple was shaped as a huge, wide obelisk (20 m wide and 36 m high) on top of a pedestal (called from now on the 'basement') in the form of a large, truncated pyramid (40 m wide and 20 m high). An ascending corridor probably went up twice all around the basement, finally reaching the base of the obelisk on the eastern side. Because of the severe state of disrepair of the whole building already in Borchardt's time, his reconstruction was mainly based on the shape of the hieroglyphic in the contemporary tomb of the fifth dynasty priest Ty at Saqqara, where the name of the temple is determined by a two-stepped building in the form of a squat obelisk on a large basement. Borchardt compared the ratio between the two parts of the hieroglyphic sign with the archaeological evidence still available on the site, including the dimensions of the core masonry of the basement, the sloping of both the granite casing at the bottom of the basement (about 76°) and a limestone block probably from the obelisk (about 81°), the surface of the pedestal at the height of 20 m, and the surface of the base of the obelisk, which was believed to stand in the centre of the pedestal. Taking into account all these elements, Borchardt estimated the total height of the complex at 56 m (Borchardt, 1905, pp. 33–40). However, although we can accept the idea that the outline of the hieroglyphic sign used to determine the name of the temple in the inscriptions approximates the actual shape of the obelisk, it is not realistic to expect an exact correspondence between the proportions of the real building and those of its representation in the hieroglyphic text. Furthermore, a number of other considerations concerning the architecture of the temple (weight, height, type of material used, nature and composition of the soil where it was built, etc. ...) lead us to conclude that Borchardt's reconstruction is not entirely sound (Nuzzolo and Pirelli, 2012, pp. 666–669).

This paper, however, will not deal specifically with all the above problems, which mainly concerns the Egyptological milieu. Rather it is an attempt to show a new methodological approach for the management and sharing of archaeological and 3D data, applied in a specific study context. This new methodological approach is the Archaeological Building Information Modelling (ABIM), by which means it is possible to produce categories of environmental and technological objects and sub-systems, which represent the 3D semantic of the acquired model.

After a short introduction on the implementation of the digital survey of the temple, the paper will focus on the strategy of analysing the core structure of the architecture and its main components. Attention will also be paid to some recent achievements and technological issues, regarding especially the conceptualisation of the architectural model. Contrary to the traditional CAD or 3D graphics approach, a BIM project represents a digital environment which enables the integration of different elements of the 3D, from the basic x, y, z properties of the geometry to the physical and functional features of the 3D object. BIM

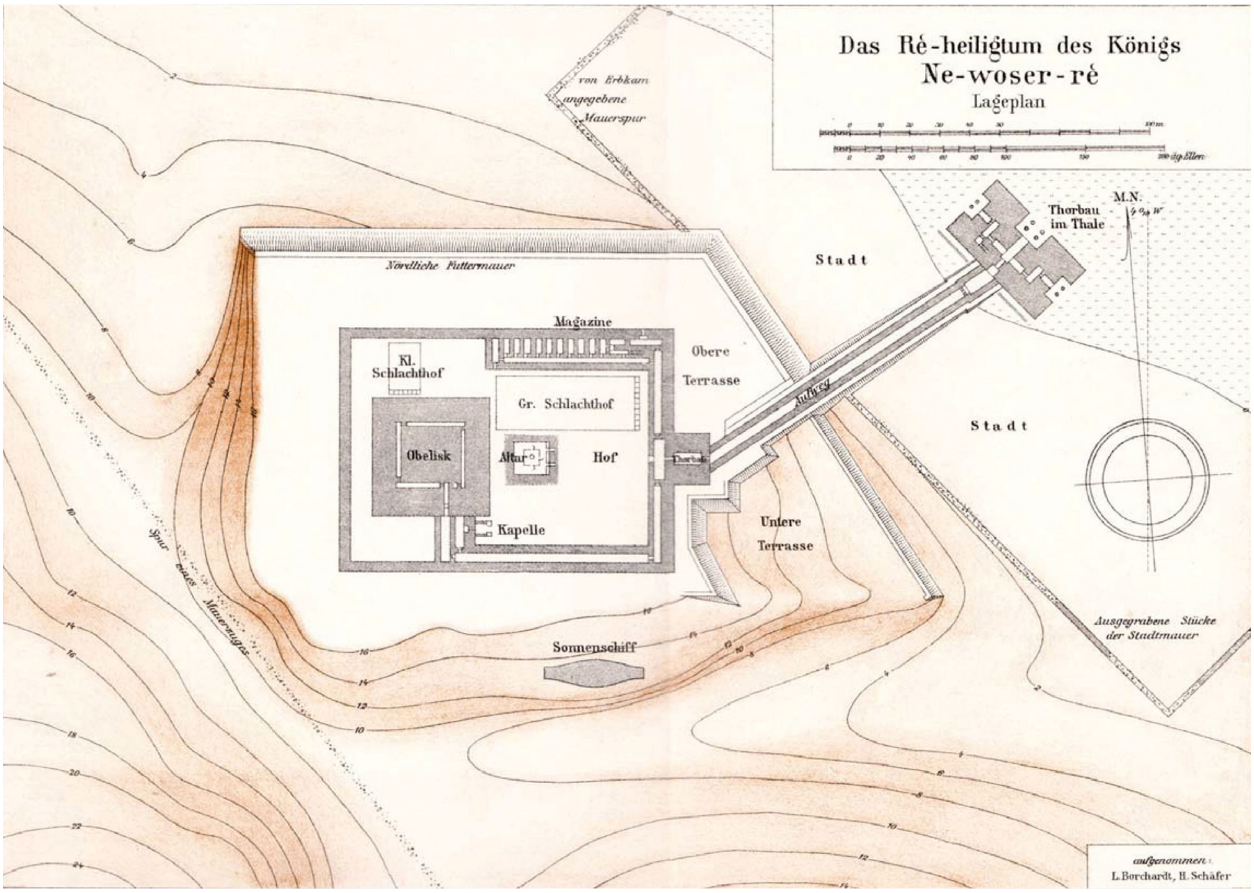


Figure 2. The Sun Temple of Niuserra. General map (Borchardt, 1905).

is a new technology (or methodology) which allows the association of different data and information useful in all phases of analysis, from the reconstruction to the conservation planning.

The digital survey

According to a well-established workflow, the work on the site has been divided in three different phases:

- Acquisition and revision of the graphical documentation of the solar complex of Niuserra and vectorisation of the most relevant archaeological features unearthed in the previous explorations;
- On-ground analysis of the state of conservation of the area and of the archaeological evidences; verification of the data acquired during the first phase;
- Design and implementation of the digital survey of the solar temple by means of 3D laser scanner and digital photogrammetry; post-processing (clearing, filtering, alignment and registration) of the shots, 3D reconstruction of the solar temple and extraction of the main graphical features (sections, elevations, plans) of the monument.

During three campaigns (carried out in 2010 and 2014) different surveys have been carried out with the aim of reconstructing the overall archaeological area of temple of Niuserra. As already mentioned, the complex presented many gaps and missing parts due to ancient and modern robbery activities, as well as to the collapse of some structures. This complicates any interpretations of the architectural remains. For this reason, the design of the data-acquisition was particularly accurate in order to avoid errors in the reconstruction; in particular, many scans from different point of views were carried out to completely acquire each single object.

To guarantee the correct roto-translation and alignment of the scans, a local grid was implemented by positioning four pegs around the temple, following the shape of a rhombus, and one peg at the top of the terrace structure. The positioning of the pegs was carried out with a total station. The topographical network was closed by linking the first and the last point, in order to reduce possible errors in measurement.

In 2010 (January and December), two different data-acquisition campaigns were carried out with the aim of surveying the Chapel and the Room of Seasons on the southern side of the temple, as well as the storehouse on the north–eastern side, and the area of the obelisk and the altar in the central part of the temple.

All scans were processed, registered and aligned on the base of the targets measured by total station. As the laser scanner cannot acquire colour data, some photos were taken by a digital camera and then superimposed, using software JRC 3D Reconstructor®, on the final 3D model in order to have a much more realistic rendering.

Finally, different maps and sections documenting the state of conservation were extracted from the model; in particular, a top view map, showing the perimeter of the obelisk, the internal corridor and the collapse of the core masonry walls on the south-western corner, was generated. Finally, some plans were built thematically on the basis of the materials of the blocks used for the outer and inner core of the obelisk. These maps were then superimposed on the original plan, drawn by Borchardt, in order to compare the reconstruction obtained from the model with the survey carried out in the last century.

In 2011, during the Egyptian revolution, the temple was partially damaged, including some parts of the floor of the court and the obelisk masonry. The main damage was concentrated in two areas:

- the room of the seasons, whose pavement was consistently broken in the centre and later on repaired, perhaps by the local guards;
- the big stairway of the so-called storerooms, in the north-eastern corner. This ramp was completely destroyed, thus losing important data for this kind of structure (in the Egyptian architecture in the same period only few remains of stairways leading to the roof top of the temple are known).

Furthermore, the topographic grid created in December 2010 was completely removed.

In 2014 a new 3D survey was undertaken using a Faro Focus 3DX130. This device mounts a high resolution digital camera, particularly useful for acquiring not only the geometric features of the temple, but also to provide a completely realistic 3D model of the sanctuary. Furthermore, the new type of laser scanner acquires geo-referenced data allowing a simpler and easier way to merge the different scans.

In 3D data–capture, special attention was dedicated to some specific areas of the temple which proved to be very problematic for both the final reconstruction of the monument and the presence of important and numerous artefacts which could be useful for the archaeological analysis of the temple and the drawing of its revised plan.

The 2014 laser scanning campaign was conducted on the whole of the temple with three main focus areas:

- the obelisk (especially its basement which is still quite well preserved);
- the area around the altar, where several inscribed blocks of granite are still visible on the ground;
- the entire enclosure wall of the monument and the main doorway of the temple (attention was here particularly paid to the analysis and scanning of blocks of the structure laying outside the wall).

In six days, 56 scans were acquired. Fourteen high resolution scans were processed and aligned and used as reference for the other ones from the previous campaigns. Then all scans were merged into one point cloud. Finally, the duplicated points were removed and the model simplified in order to have a lighter 3D reconstruction without losing any information useful for the interpretation (Figure 3).

To reach a more realistic rendering of the archaeological area, the laser scanner campaign was integrated with several acquisitions by image-based modelling. The integration of the geometric precision of measurements by laser scanner with the high resolution texturized surfaces by image-based modelling approach, allows us to analyse in detail the remains and to provide information about the materials and architectural elements of the sanctuary.

Some critical areas, fundamental for the reconstruction of the obelisk and the entire monument, were in particular acquired by the image-based modelling method:

- the main Gate of the temple;
- the area of the so called 'Slaughterhouse, especially the area of alabaster basins (Figure 4);

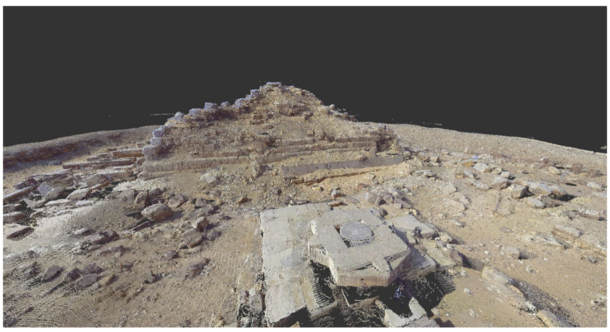


Figure 3. The 3D model of the Sun Temple of Niuserra after alignment of all scans.

Figure 4. The 3D model, by image-based modelling, of the area with alabaster basins.

- the collapsed blocks laying at the bottom of the obelisk at its south–western corner.

Data acquisition has been carried out by a reflex Canon 450d with 18 mm lens. For each area, an entire working day was spent. The photos were processed by Agisoft® Photoscan®. Some targets were positioned close to the areas to be investigated in order to scale the model according to its real dimensions. To check the precision and accuracy of the model, some points were also extracted from the scans in order to geo-reference the model to the grid taken by the laser scanner. At the end of the processing different models (point clouds and mesh) were rendered.

All the 3D data were, finally, merged and analysed to highlight the damages caused to the archaeological structures after the 2011 revolution. Moreover, many annotations, associated with short descriptions, were taken for those blocks and architectural elements which were collapsed and had not been placed by Borchardt when the temple was discovered.

The digital archive so far produced contains some Tb of data, which are not easy to manage with traditional methods. On account of the increasing volume of acquired data, in 2014 a new approach started to not only facilitate a typical scientific workflow (formulation of alternative hypothesis about the reconstruction of the obelisk, analysis of the structural architectural elements still *in situ*, creation of plans, sections and drawings), but also to create a more advanced model for data-sharing which may eventually facilitate the study of the relationship of the temple with the surroundings monuments and the local environment. The next paragraph examines in detail this new approach, in particular the design of the architectural project, the preliminary results so far achieved, and future perspectives.

The BIM approach

The acronym BIM defines a new methodological process of modelling architectural data and not simply a graphical software for 3D modelling. To be precise over the correct interpretation of BIM, it is necessary to recall, among many others, the following two definitions:

1. BIM involves representing a design as objects — vague and undefined, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. The geometry may be 2D or 3D. The objects may be abstract and conceptual or construction detailed. Composed together these objects define a building model (not a BIM, in my view) (Eastman *et al.*, 2008).
2. Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition (National Institute of Building Sciences, 2016).

According to these definitions, BIM is a philosophy or a process to design, collect, share and manage different data sets. BIM has been formerly employed for modern civil engineering to integrate the needs of the designers with the world of the building companies and industries. From this point of view, BIM has been implemented to facilitate the design and management of new buildings by creating a digital environment accessible by different stakeholders. Notwithstanding these native features, BIM has also been applied to manage existing and historical buildings. In 2009, some scholars (Murphy *et al.,* 2009) introduced the definition of H (Historical) BIM to describe an approach focused on the conservation and virtual reconstruction of ancient buildings. Later Murphy (2012) highlighted that HBIM is '*a novel prototype library of parametric objects, based on historic architectural data, in addition to a mapping system for plotting the library objects onto laser scan survey data*'.

Even if BIM had not previously been implemented for built heritage, the need to share and combine several categories of data into a unique system, such as the state of conservation, the description of single architectural elements, information about spatial organisation of the buildings, the use or the reuse of spaces and objects, the classification of objects, encouraged different scholars to apply this new approach to cultural heritage. The main challenge of BIM is therefore to manage different data sets relating to a building during its complete life-cycle by including spatial and alphanumerical data. In wider terms, BIM can be considered as an evolution of GIS in a 3D environment, as it associates geometric and spatial element to attributes and relationships among objects (Tobiáš, 2016); 3D alphanumerical and spatial data about the architecture of a building can be integrated in BIM as 2D objects are integrated into a GIS.

A strong advantage of BIM is the possibility to freely share 3D data from various sources, providing to various experts the access to the same model. Thanks to BIM, each user can access, analyse and modify whatever part of the model by participating, actively, in the same project. BIM encourages the various actors to collaborate, without obliging them to acquire a new language. In the end, BIM is the result of different and interconnected models which exchange and share data coming from topographical investigations, laser scanning or digital photogrammetric surveys, or traditional modelling techniques.

Contrary to the CAD approach, the 3D modelling BIM is based on parametric elements representing all physical and functional properties of whatever architectural object with its spatial relationships. The model is therefore described through a formal representation highlighting concepts and categories (Murphy *et al.,* 2011).

To reach this target software companies are developing a common format to facilitate data exchange. Industry Foundation Classes (IFC) is becoming the standard as it can guarantee a reduced loss of information in the exchange among the different applications and actors. This format allows the creation of a virtual and common repository where anyone can store and share information concerning the geometry of a building or its material or historical information.

Whilst in modern civil engineering the libraries of parametric elements can be easily implemented and shared, in the field of HBIM there are not libraries suitable for the 3D reconstruction. If, in built heritage, the architectural elements are frequently well preserved (Quattrini *et al.,* 2015) and therefore the creation of categories of objects is a quite simple task, whereas in the archaeological context the structures are very often badly preserved and only partially visible or strongly restored or modified compared to their original shape. The absence of shared libraries has probably made the application of BIM more difficult for archaeological monuments and sites (Scianna *et al.,* 2015; Garagnani, 2012).

Currently in HBIM field, researchers are facing two main challenges:

1. the creation of standard libraries of architectural elements sourced from data acquired by digital surveys (laser scanner and/or digital photogrammetry) (Brumana *et al.,* 2013; Oreni *et al.,* 2014);
2. implementation of tools to facilitate the re-modeler of the 3D data point clouds according to parametric libraries (Chiabrando *et al.,* 2016).

Our project deals with the design of a specific library for the technological system adopted in the building of the monument. The next paragraph focuses on the workflow developed for the implementation of BIM; in particular, we face the formalisation of data based on an innovative composition and decomposition of all the architectural elements.

A BIM model for the Sun Temple of Niuserra

Thanks to the campaigns carried out up to and including 2014, the temple of Niuserra was completely surveyed. As BIM deals with the environment and technological systems, the first step was the analysis of the architectural model in order to facilitate the composition and decomposition of all elements according to different levels of detail. From the 3D model architectural information was extracted about the building and the masonry. All the blocks and slabs were singularly analysed in order to highlight elements showing the design and the building of the different structures. This preliminary work allowed us to correctly formalise the whole complex according to UNI 8290–1981 classification set-up for building systems. It consists of:

> PART ∩ COMPONENT ∩ SUB-SYSTEM ∩ ELEMENTARY SYSTEM ∩SYSTEM
> (∩ = it belongs to)
> SYSTEM — It corresponds to the whole Solar Temple;
> ELEMENTARY SYSTEM — It consists of classes of technological units and the main systems for the working of the temple: structure system, closing, internal and external partitioning, etc.;
> SUB-SYSTEM — They are the technological units of each elementary system, as the foundation and horizontal and vertical partitioning, etc.;
> COMPONENT — They are the classes of the basic technical elements as architrave, jambs, internal and external walls, etc.;
> PART — It includes each element identifiable as a component like blocs, slabs, etc.

Even though this classification has been developed for modern civil buildings, it fits well with the features of Egyptian architecture, which shows the following main elements: Simplicity; Modularity and Standardisation; and Portability.

While in the previous approach, the 3D survey was mainly used to extract 2D sections and maps useful to document the shape of the monument and its state of conservation, thanks to BIM it has been possible to setup a wider workflow allowing the creation of spatial and geometrical 3D objects enriched by a formalised description. The first step of this new project was the import of the scans into a BIM. To clean and merge all scans in only one point cloud, which is more easily managed by BIM, all 3D data were imported into Autodesk® Recap®. The processed point cloud was then imported into the software BIM Revit® by Autodesk®.

As Revit uses a different language to describe the technological system, one of the main tasks was to map the categories of schema based on the UNI standard onto conceptual groups of Revit. This is the final mapping:

UNI	**Revit**
System	Family
Sub-System	Type
Component	Instance

Even though BIM has been developed to design new buildings, in the case of Niuserra, and usually for HBIM, this approach was upturned; HBIM has to start from the visible evidences on the ground to achieve the reconstruction of the prototype of the monument.

Thanks to BIM, the concept of drawing or modelling of whatever building can be easily completed and enriched by creating a new and more complex workspace. The new model is a simulation and shared laboratory in which we can rebuild the different phases of the construction process ranging from single blocks to the entire building.

As different parts of the temple had been partially damaged, because of the continuous reuse of stone in antiquity, it was fundamental to localise the exact positioning of the no longer *in-situ* architectural elements. The technological system was probably also used in the contemporary and nearby pyramids, and therefore some missing architectural elements were based on the analogue remains in Abusir.

From the analysis of the conceptual model, some categories of architectural elements, corresponding to different components of the technological and constructive system, have been extracted (Figure 5).

These semantic parts contribute to the formal and physical representation of the 3D reconstruction of the monument: on the basis of the 3D survey, different 3D geometrical objects have been created and associated to a description including code, material, dimension, and provenance (Figure 6).

Each element of the sub-system has then been analysed and correctly assigned to a specific category. Revit allows the creation, in the architectural model, of a taxonomy including families, types and single instances. As Revit has been designed for industry, a fundamental step of the project implementation was the creation of a new parametric library which included a detailed description of all archaeological artefacts. Thanks to this formalised data-organisation, called ABACI in Revit, BIM allows us to associate physical instances to graphical, photographical and archival information (Figure 7). The database can be easily queried and the geometrical objects visualised. In this way, BIM works as 3D GIS.

The conceptual design of Revit, particularly flexible in the starting phases, allows to analyse all components and to create classes or entities of standard volumes which can be integrated in the model. These entities can be progressively converted into virtual building materials; detailed architectural elements can be created (walls, roofs, pavements, etc.) on the basis of their volumetric families. In this way, one can also easily calculate the amount of building materials necessary for the construction of each part or sub-system of the

TECHNOLOGICAL SYSTEM

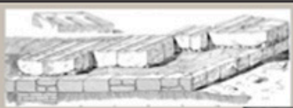
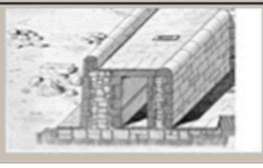
classes of technological unit	technological units	classes of technical elements
Closing. Set of technological and technical elements of the building system with a function to separate and to conform the interior spaces of the building system itself than outside.		
	**vertical closure** set of vertical elements of the technical building system with a function to separate interior spaces of the building system itself than outside.	- perimeter walls - vertical external fixtures
 	**lower horizontal closure** Set of horizontal technical elements of building system having function of separating the interior of the building system itself from the underlying soil or the foundation structures.	- Slab on the ground - horizontal fixtures
 	**Horizontal closure of outdoor spaces** Set of horizontal technical elements of building system having function of separating the interior of the building system itself by underlying external spaces.	slabs of open spaces
	**top closure** Set of horizontal technical elements of building system having function of separating the interior of the building system itself from outer space above	- covers - horizontal external fixtures

Figure 5. The Technological System schema for the closings of the temple.

temple and evaluate what it misses or what has been destroyed (Figure 8).

In order to better analyse the final reconstruction, the model was contextualised into surrounding territory. By assigning correct geographical coordinates it was possible to visualize the monument in its landscape and to improve the rendering of the building material according to the positioning of the temple. This approach is particularly useful to not only generate correct shadows in the animation, but also to deepen the spatial location of the monument, as it was probably used as astronomic point of observation. Furthermore, Revit allows the visualization of the reconstruction in Google Earth®. This overlapping was particularly useful to better understand the artificial terrace system used for the foundation of the temple.

Different historical maps were used to analyse the creation of the complex. As hypothesised by Borchardt, Niuserra's temple was installed on a previous building whose traces are still partially visible on the ground. To attempt to identify the two monuments (or layers of a single monument) the reconstruction was superimposed onto the old map provided by Borchardt (Figure 9).

The reconstruction allows us to hypothesise some alternative proposals. In particular, the simulation of horizontal planes and rebuilt structures can also help us in the understanding of the original architectural structure of some of the temple components. This is extremely important for the obelisk, whose shape has not yet been clarified and represents one of the main targets of new investigations. The superimposition of the point cloud onto the conceptual mass of the obelisk highlights the co-planarity of the planes and volumes of the building. In some areas, phenomena and dynamics of collapse or movement of the blocks can be better identified, and therefore useful for the final reconstruction of the monument (Figure 10).

Another example is provided by the south–eastern area. Here it has been possible to understand the outflow system of the liquid by creating a virtual plane among the few visible remains of the pavement with the alabaster basins positioned along the South walls.

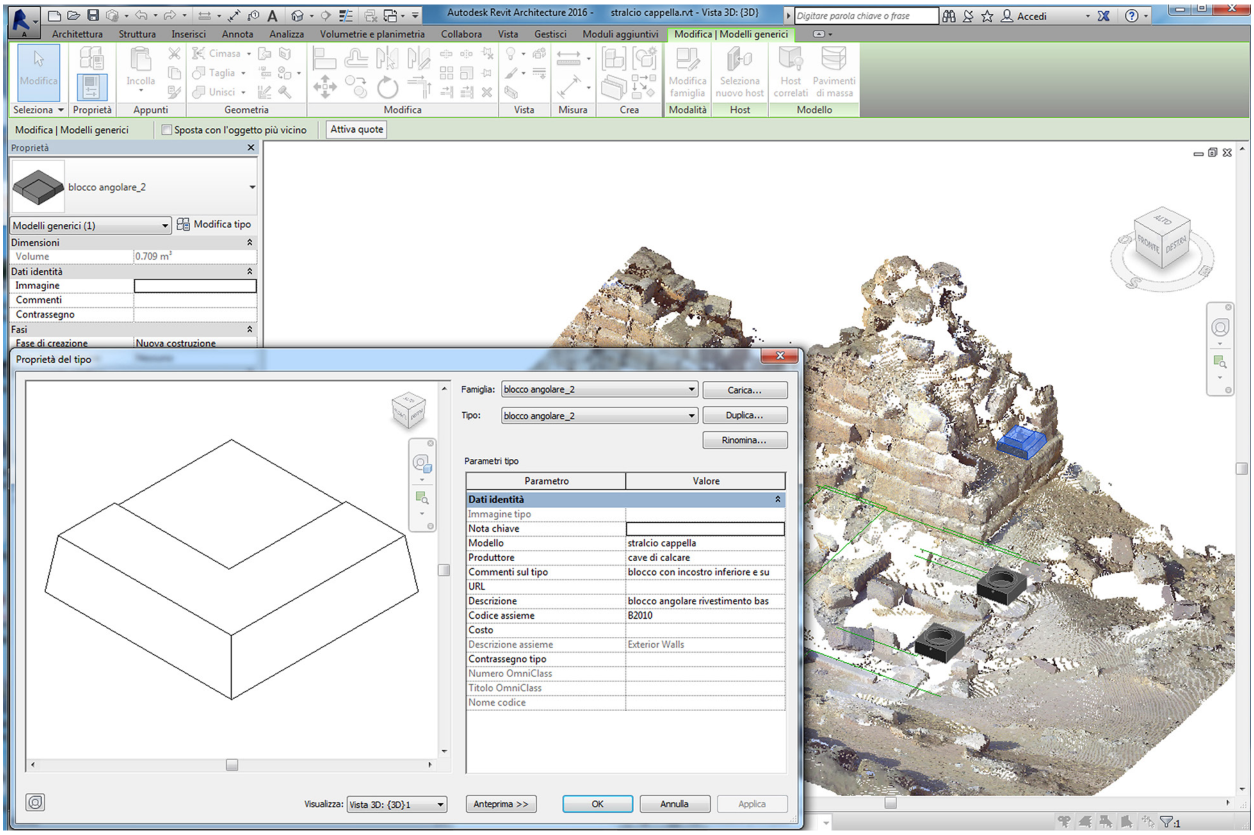


Figure 6. An example of types: an angular block (highlighted in blue) and its description.

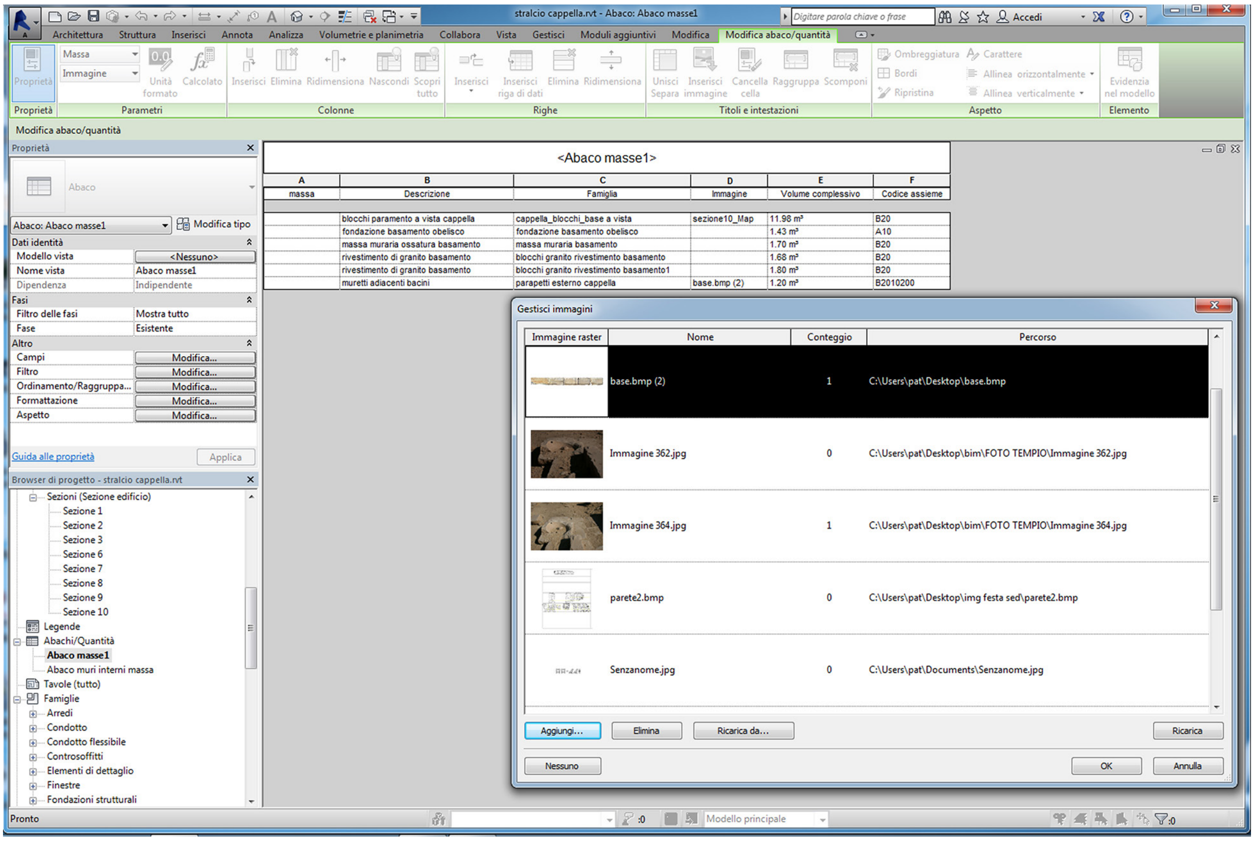


Figure 7. A list of some components of the Sun Temple of Niuserra associated to the images.

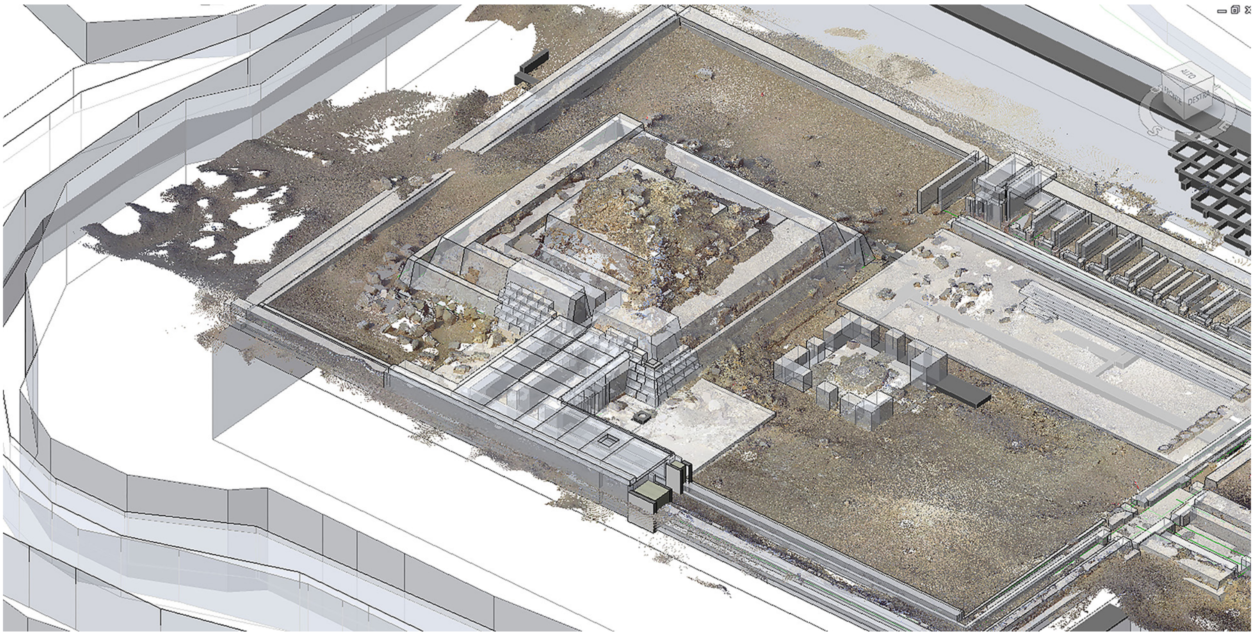


Figure 8. The visualization of the 3D model of Niuserra; in particular, different rebuilt blocks superimposed on the digital acquisition

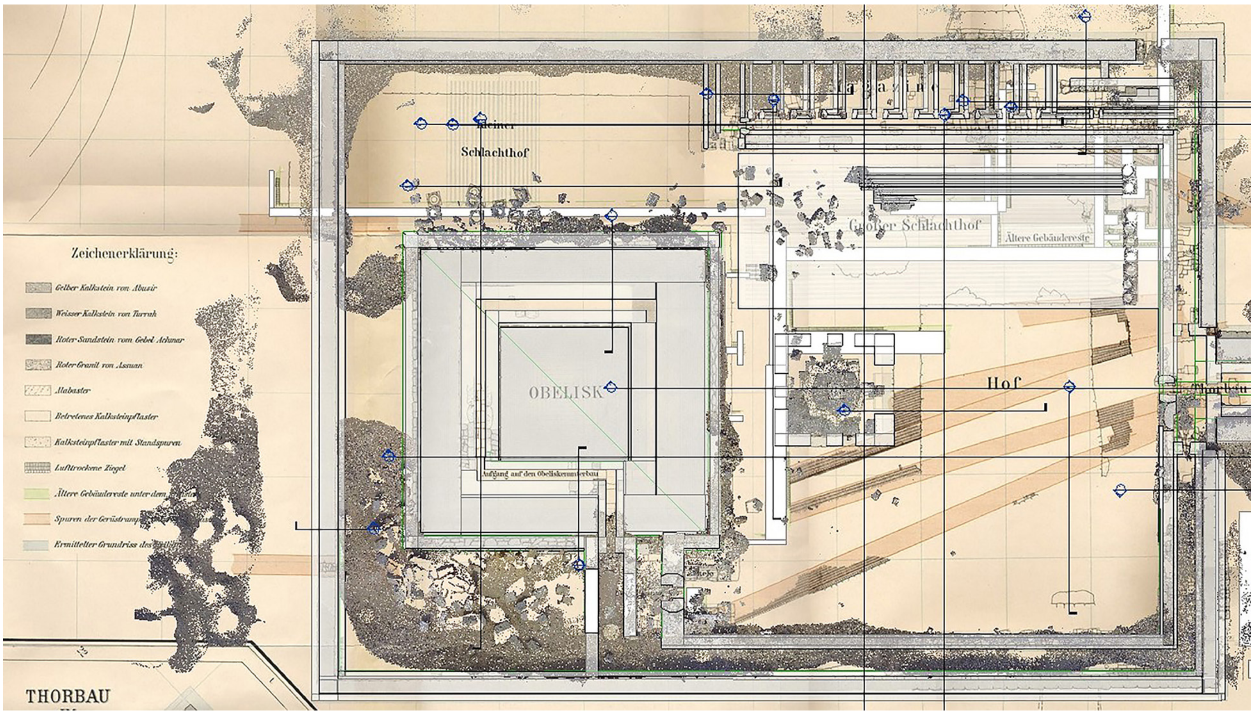


Figure 9. The superimposition of the reconstruction onto the Borchardt's map.

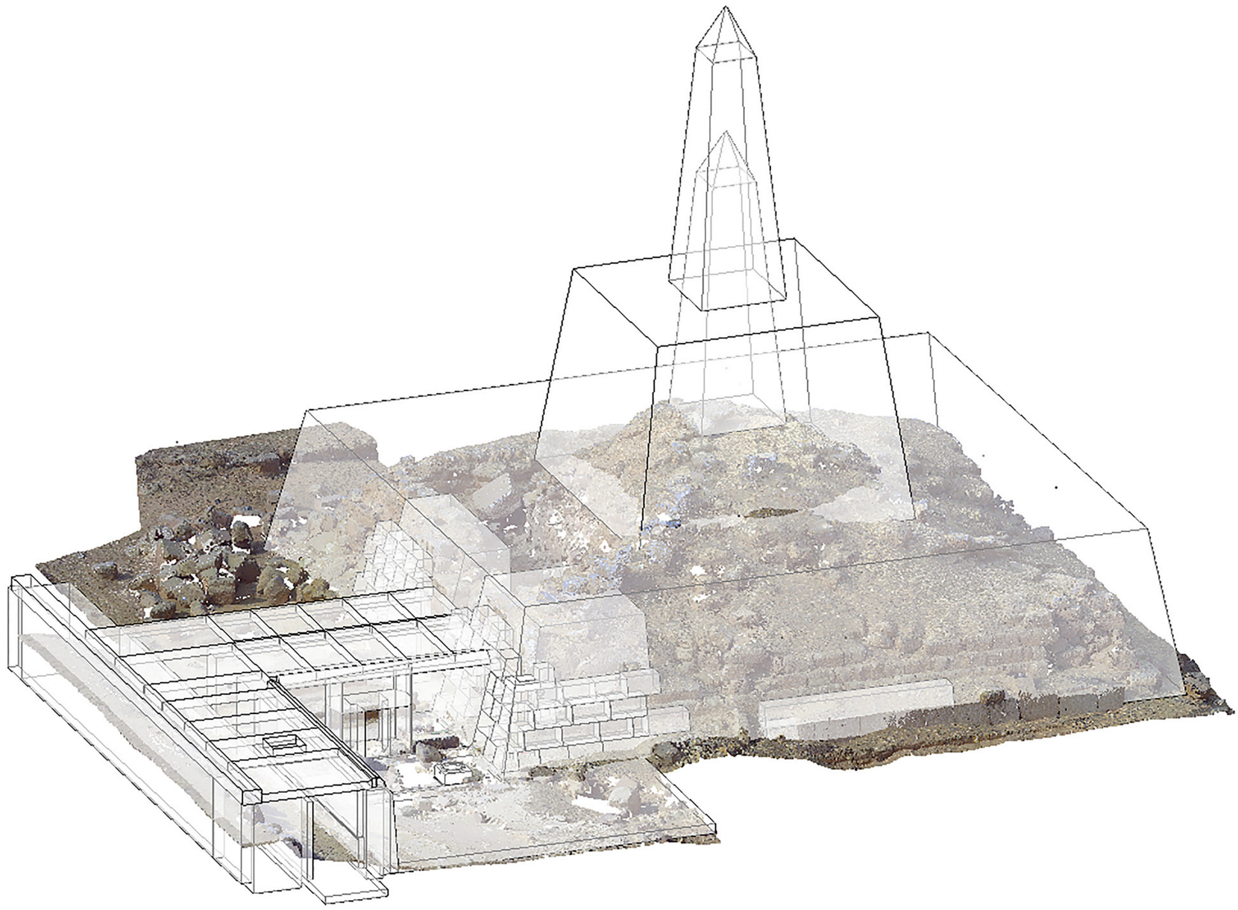


Figure 10. The comparison of two alternative hypotheses about the height of the Obelisk.

Conclusions

The paper dealt with the preliminary results of a BIM implementation for an Egyptian monument characterised by many missing parts which do not allow a precise reconstruction by means of traditional methodologies. The model is based on a number of highly accurate scans and 3D models by photogrammetry, and it is finally enriched by a detailed description of all the available architectural elements (either masonry blocks or decorative slabs and other decorative elements).

The BIM approach, which is currently underdeveloped in archaeology, was started in 2015, replacing the previous approach based on a traditional 2D Geographical Information System (GIS). The architectural model includes environmental and technological categories which allowed for a preliminary analysis of the static position and orientation of the building, as well as of the sun positioning. To enrich the graphical model of the temple, an objects library has been implemented in order to describe the structural elements formalised as categories and families according to Revit. All data are fundamental to investigate the use of the monument in antiquity and the following destruction, which probably started already during the pharaonic period.

The BIM gives us the possibility to create a semantic structure including different levels of parametric objects and types. This library can be reused to describe contemporary monuments which are dated to the same period and have similar functions. The standard format (IFC), which collects all information, ensures the exchange of data among different scientists and experts with no lack or loss of information.

In this way, the final model can be easily exploited by various experts to start a new analysis regarding the static, the seismic and the possible causes of the collapses. All this information is also necessary to plan eventual restoration projects or valorisation initiatives.

The BIM, in the specialised applications as HBIM and A (Archaeological) BIM, is a new and reliable approach for the representation of built heritage. It associates the high quality of the model with an accurate geometry and a detailed description of each component of the architectural system. For these features BIM will play a fundamental role in forthcoming years in the management and sharing of 3D content. Thanks to the possibility to encapsulate the semantic in the model, BIM will soon become a virtual laboratory for cognitive systems in archaeology.

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