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Pretty and Useful? – Three-dimensional Computer Models as a Working Tool for Documentation and Investigation in Building Archaeology

Abstract: The application of three-dimensional computer models for the visualization of ancient architecture has increased rapidly in recent years. Yet when such models are used only to show pretty pictures, their full technical capacity is reduced to that of presentation tools. The use of 3D models offers greater potential if it is integrated into the working process itself. The documentation of artistic artefacts and the modelling of complicated structures for detailed investigation are just two possibilities. The type of model chosen and the technical aspects of how it is created and presented all depend on the intended results. Two ongoing research projects will be presented as examples to demonstrate and to discuss different ways of utilizing 3D models.

Introduction

Increasingly, digital 3D models and rendered pictures have become a natural part of archaeology and building archaeology¹. They allow ideas to be illustrated clearly and complex findings to be visualized. Meanwhile the technical progress in the field of computer graphics is providing the possibility of designing the “perfect” view into the past. At the same time, new surveying techniques are allowing artistic artefacts and architecture to be recorded to any desired degree of accuracy. Millions of points can be generated to get an exact virtual copy of the original. In fact computer graphics, CAD and surveying technologies offer researchers a large number of powerful tools and possibilities not only for visualization but for the working process itself. For this reason, it seems necessary to take a closer look at strategies and methods of 3D modelling and to distinguish different types of models.

Defining “Model”

Looking up the term “model” in various dictionaries, one finds three common definitions applicable

to 3D computer models. First, a model is a representation of something, usually smaller than the original. Second, a model is a design that serves as an example for imitation or emulation. Third, a model is a simplified description or analogy of a system for explanation, calculation, etc. In this case the model facilitates the visualization of such a system.

In terms of archaeology and building archaeology, these definitions can be understood as follows: the first definition describes a very accurate image (or copy) of the original; that is to say an exact geometrical representation, as needed for the documentation of artistic artefacts or architectural remains. The second definition applies to the re-creation of an object through the process of 3D modelling, as is already commonly used to illustrate reconstruction ideas. The third definition is not relevant to archaeology, as it refers to design and planning, where the model is a simulation of spatial and constructional features. Consequently, there are two different kinds of models used in archaeological research. They shall be referred to as “Image” and “Re-creation”.

¹ The term “building archaeology” refers to a specified approach to research in history of architecture. The building itself is seen as the main source of information. A detailed documentation is the primary concern and the foundation upon which the analysis is conducted. On this topic see Schuller 2002.

Re-creation

A re-creation² is a synthesis of all the different kinds of information available in the original. This can include survey plans and documentation of the remains as well as written sources and pictures. A re-creation is an abstract description which can include the results of an investigation as well as hypothetical reconstructions, or even just the illustration of an idea. Therefore a model re-creating the original – even without any reconstruction – is always the result of an interpretation and a representation of scientific results (KNOLL et al. 2004). The modelling is usually done in CAD-software using 3D lines, planes and volumes. Applying attributes to those geometric models such as colour, material or transparency supports visualization, and mapping photos onto a model offers an even more complete description of the object.

The construction of a 3D model involves re-creating the original construction process, which necessarily requires an analysis of the object's design. Complex spatial organisation or different building periods can be discovered during modelling. Thus the reconstruction process itself generates new information. Because of the decisions made during this process, the model is designed for a certain purpose and cannot be used for any other. In this way the re-creation reveals the intentions of the author. Nonetheless, the observer of a complex three-dimensional model often infers and associates much more than was intended. That is why codes of visual perception, data transparency and the level of detail have to be kept in mind (HERMON et al. 2006).

Image

Unlike a re-creation, an image is a precise copy of the original's 3D information. As such it does not contain any interpretation, but is pure geometric documentation. New three-dimensional surveying techniques such as digital stereo photogrammetry and different scanning techniques now allow one to record data to any desired degree of accuracy. Using these techniques, we can create geometric

representations which have virtually the same three-dimensional information as the original. The resulting model describes only the surface, which can be additionally textured with photos to describe its material and colour. Even information not visible on the surface can be integrated into the model, for instance, that of computer tomography.

These new surveying techniques can be used to collect highly accurate data that does not contain any level of interpretation and could be termed objective geometric documentation. The three-dimensional image is not an investigation itself, but rather a basis for drawings and subsequent investigations.³ To a certain extent it ensures further scientific research even if the original is no longer accessible or destroyed. Furthermore, images can be used to make reproductions, for instance, to replace endangered originals by replicas.

Case studies

In the following pages, two ongoing research projects are presented as examples to demonstrate and to discuss the two different kinds of 3D models. For the investigations of the "Domus Severiana" on the Palatine in Rome an abstract CAD-model of the complex remains – a "re-creation" – was assembled. At the excavation in Naga, Sudan, 3D models – "images" – of different objects were generated by scanning instead. In both projects the 3D models are used as a working tool to handle the existing ancient remains.

Investigation of the so-called "Domus Severiana"

The investigation of the so called "Domus Severiana" on the Palatine is a cooperative project between the German Archaeological Institute Berlin – with its head of the Architecture Department, Dr.-Ing. U. Wulf-Rheidt – and the Brandenburg University of Technology in Cottbus. The project started as part of the preparations for the restoration associated with the event of ROMA 2000. At that time the Soprintendenza Archeologica di Roma commissioned different teams to investigate sections of

² The term re-creation is not used consistently in literature; see for instance FAVRO 2006, 322. I will use "re-creation" to refer to the process of recreating the object as a model (of an existing original as well as of an interpretation like a reconstruction).

³ Images as the basis for a new kind of 3D-documentation are discussed by SCHAICH 2006.

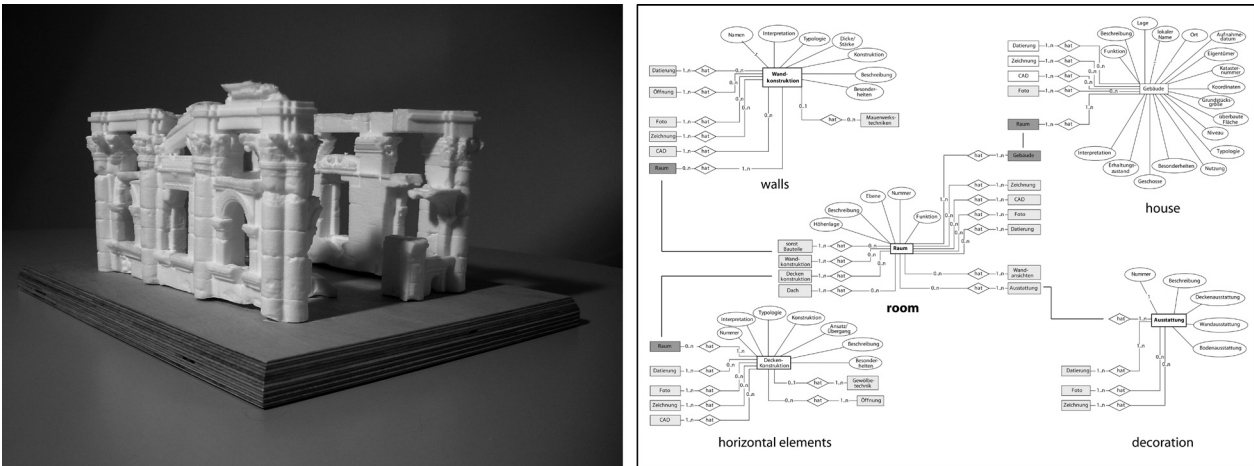


Fig. 1. Definitions of the word “model”: representational model of the so called “Roman Kiosk” in Naga (left), descriptive model of a database concept for the room inventory of the “Domus Severiana” (right) (G. Neumann).

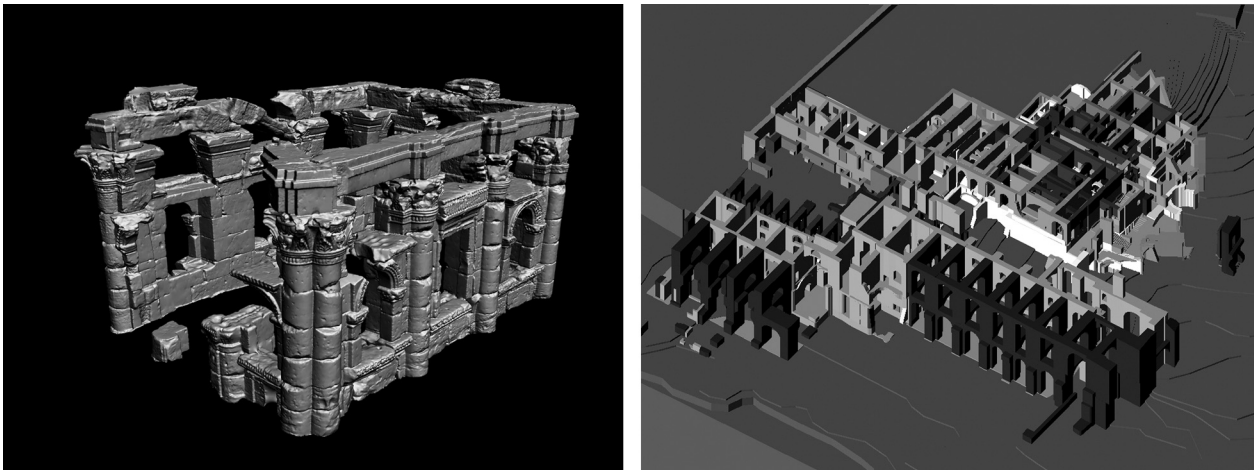


Fig. 2. 3D models in archaeology and building archaeology: Image (left) and Re-creation (right) (C. Brasse).

the palace that had been hitherto neglected. For the ruins of the “Domus Severiana,” the most southern part of the palace, this had been particularly the case, and little was known about its development and former appearance.

The complex structure of the “Domus Severiana” is as high as 48 m in some places and in relatively good condition. It consists of a highly complicated system of rooms extending over several storeys, like a labyrinth. Of the architecture that rose above the main floor and the marble ornamentation only a few fragments have survived. Because investigations into the complex have always been complicated by missing or confusing plans, the primary concern was the documentation and visualization of the structure. In five campaigns over a total of twenty weeks, this part of the palace has been documented

in five ground-plans and nine sections. This documentation of the building is the foundation upon which the structural and historical investigation of this part of the imperial palace can be conducted. The individual observations of building details (such as joints, seams, types of brickwork, foundation techniques, vault techniques, as well as surface and decorative details and brick stamps) were recorded in a room inventory, which allows for the systematic registration of all relevant details for the 186 rooms or partial rooms. Based on the detailed analysis, six main phases from the Flavian time to the era of Maxentius were identified which are summarised in colour-coded plans.

From the very first documentation campaign on the Palatine, it became clear that the complex structure and the abundant information on construction

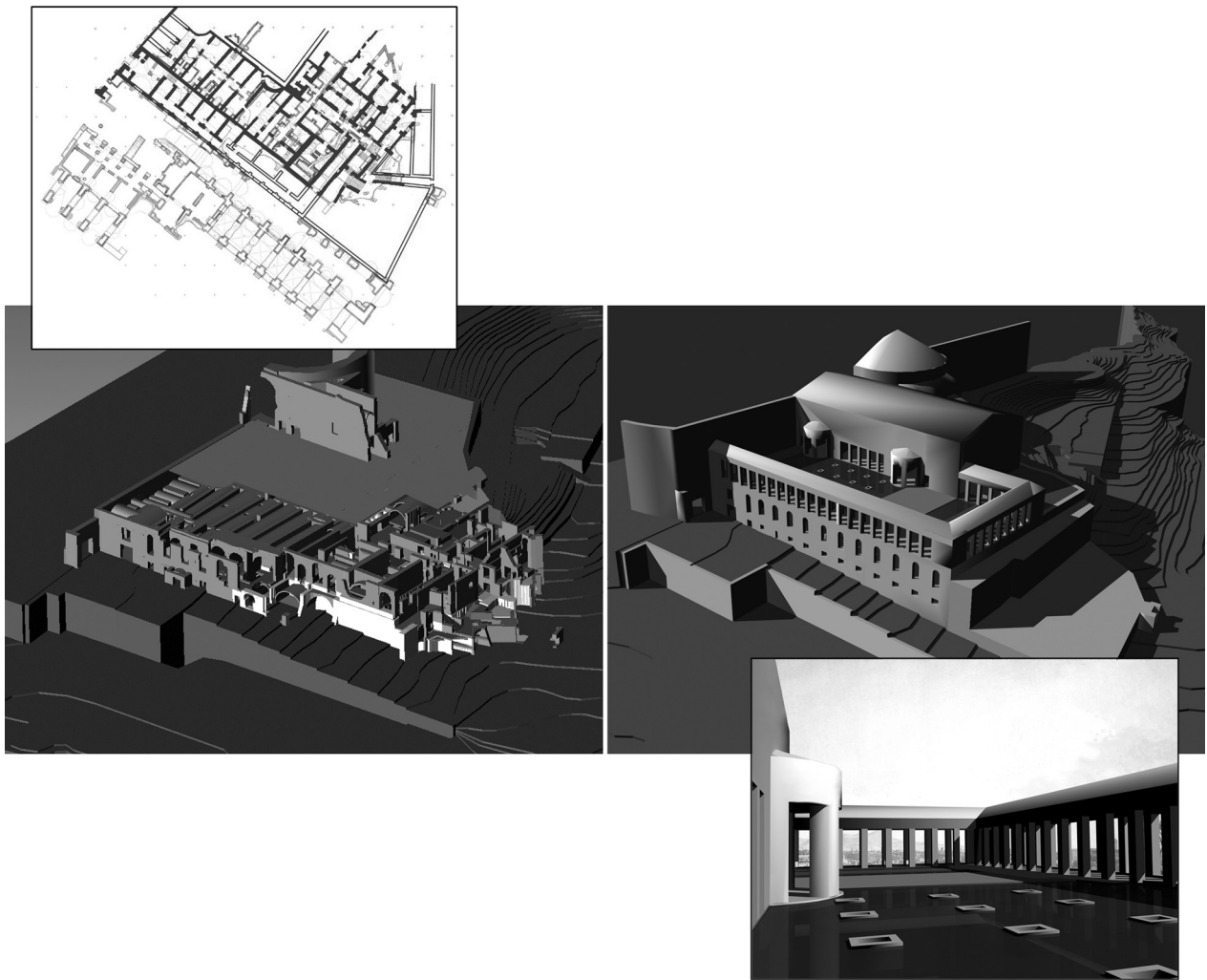


Fig. 3. Re-creation of the “Domus Severiana”; work flow from survey plan and digital model of the remains to reconstruction ideas (U. Wulf, C. Brasse).

details as well as indications of different building periods could not be presented by two-dimensional plans alone. In order to recapitulate the findings three-dimensionally, an abstract representation model – a re-creation – was assembled by means of simple 3D cubes. Upon the foundation of the survey plans and the room inventory, the single construction elements of each room were modelled such as the walls, the vaulting and the floor. As in the plans, construction phases have been highlighted in different colours. The precision of the re-creation cannot correspond precisely to the criteria used for the documentation of the building because the amount of work required would not be justifiable. Therefore the digital model shows the irregularities and particularities of the structure, but it does not give a detailed rendering.

One result of the re-creation of the “Domus Severiana” is a visualization of the existing remains of the building. Moreover, the digital model serves as a working tool for analysing the structure and can be used as a basis for modelling reconstruction ideas within the different building periods. Assumptions related to construction sequences or to the use of and access to different building units can be checked quickly by referring to the appropriate visualization in the re-creation. Interior perspectives, view axes as well as outlooks and vistas can be simulated. The process of 3D modelling itself enables the building archaeologist to redo the ancient construction and design. Just as an architect works with a model to visualize the idea behind a building, the archaeologist uses the re-creation as a working tool for reading and understanding what nowadays is no longer obvious.

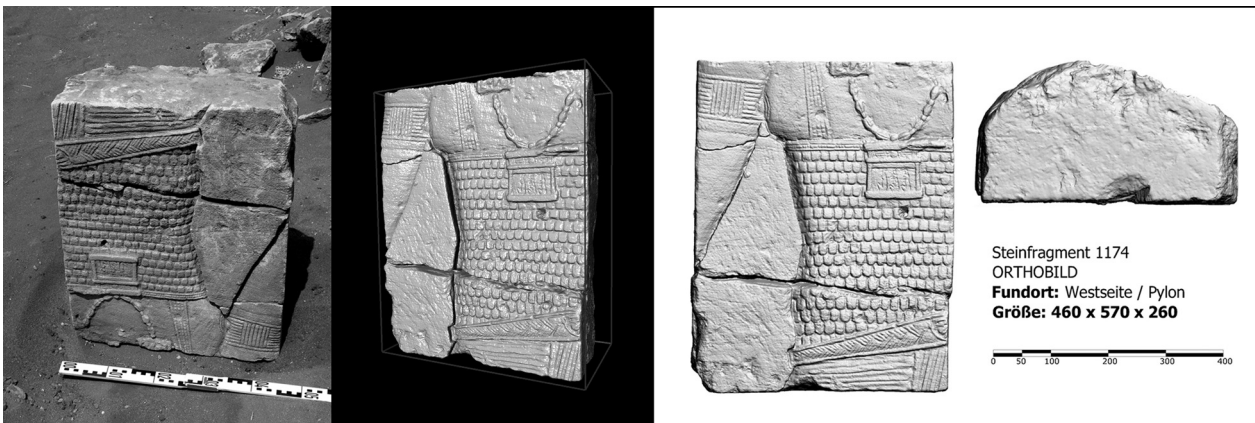


Fig. 4. Image of an excavated relief of the Temple 200 in Naga, a non-interpreted documentation.

Alongside the capacity for re-creation, the development of a web-based database was initiated at the Brandenburg University of Technology in cooperation with the German Archaeological Institute Berlin. CISAR, a comprehensive information system, was designed to combine geometrical data with thematic information as needed for archaeological research and analysis of complex building structures. Designed to allow flexibility and adaptation to a wide range of research projects, the system consists of basic and specific data modules. The basic modules include photo-, plan- and literature-databases and are used as a common foundation for all projects. Specific modules such as databases for architectural fragments or archaeological findings are created in accordance with the needs of each specific research project. For the investigation of the “Domus Severiana,” a digital room inventory and a connection to the digital model were developed. This combination allowed a building information system to be assembled, serving as a research working tool and digital archive. Every construction element is linked with the room inventory and therefore to all information available in the database.

The re-creation is used as kind of a navigator. On the other hand, the results of a database query can be visualized directly in the digital model. In this way all scientific results as well as the basic information of the documentation are accessible for the “Domus Severiana” project and data transparency is realised. The concept and implementation of CISAR as well as the combination with geometrical information in a multiscalar GIS and a 3D building information system are presented elsewhere (HENZE/LEHMANN/LANGER 2008; HENZE 2008; BRASSE et al. 2008).

Excavation in Naga, Sudan

The city of Naga, located approximately 150 km northeast of Khartoum, is one of the most important Meroitic sites of the Sudan. Lying 37 km east of the Nile in the Wadi Awatib, it has been known to scholars since the early 19th century but has never been excavated. In 1995 when the Naga Project of the Epytian Museum, Berlin began its work directed by Prof. Dr. D. Wildung, the first step was to document and investigate the complete city. Besides the compilation of a detailed map of the city area, the main aims of the project are in-depth investigations of the most important or most endangered buildings and the establishment of an archaeological park. In collaboration with the Sudanese Ministry and the National Corporation of Antiquities and Museums, the site will be developed in an appropriate way to retain its cultural significance and to allow for an appropriate level of “soft” tourism.

The archaeological site of Naga, with its partly well-preserved monuments, covers an area of two square kilometres. The palaces and houses, various temples, a huge number of graves, two water reservoirs and a stone quarry date back to the city’s period of prosperity from ca. 200 BC until 300 AD. In Meroitic times Naga was one of the royal cities used by the kings to reign over their vast kingdom. It functioned as a kind of a palatinate and besides its political purposes it also served as an important cultic centre, as is evident in the imposing temple complex of Amun and the large number of smaller temples. As a foundation for further investigation, the primary concern was over the documentation of the whole site. In seven campaigns, the city area including the topography, the graves and the remains

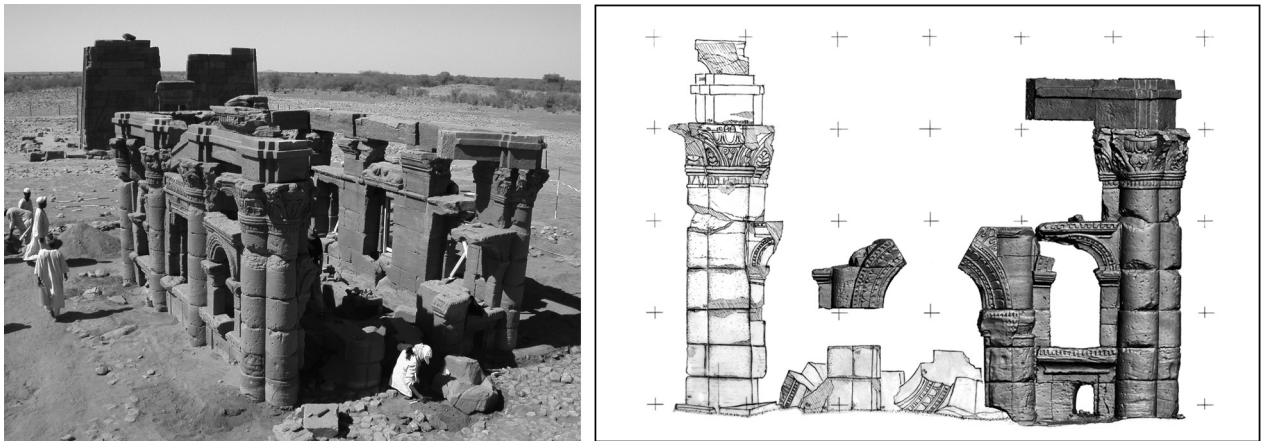


Fig. 5. The digital image as a working tool for documentation and reconstruction of the so-called “Roman Kiosk” (D. Wildung, M. Jannaschk).

of the houses, which are only slightly covered by sand, were recorded. Additional detailed investigations were started on the temple complex of Amun and the smaller Lion-Temple. An international team of archaeologists, surveyors, architects and restorers is working together to excavate, document and consolidate the ancient remains.

In 2004 the excavation at the so-called Temple 200, a smaller complex located axially to the temple of Amun, revealed a large number of decorated stones. The temple is also part of a complex consisting of a main temple, an altar and a kiosk all of which had collapsed and were subsequently covered by sand. Almost all architectural fragments and reliefs of the outer and inner walls of the temple are still found *in situ*. The high quality of the reliefs and the undisturbed context makes them outstanding objects for investigation. Unfortunately the blocks are made of a soft sandstone, which cannot withstand today’s climate without rapid decline. Because of their vulnerability and the sheer number of finds (to date 2000 blocks have been found), a standard documentation and interpretation based on the original object was not possible. Therefore in a four-week campaign in 2007 the first 550 relief blocks were recorded with a close-range triangulation scanner. Using this surveying method a digital three-dimensional model – an image – of every relief block was generated. The surface model has an accuracy of 0.4 mm and reveals even the smallest details of the relief as well as the traces of the stone masonry. As an exact copy of the geometry, the digital model is a foundation upon which the detailed investigation can be conducted. Moreover, in case of a total loss of the original, the image, as non-

interpreted documentation, will assure ongoing research.

Another example of utilizing a digital image is the conservation and restoration of the so-called “Roman Kiosk” in Naga. This Hathor-Chapel next to the Lion-Temple is the southernmost recorded building influenced by Ptolemaic and Roman architecture. The small building appears particularly well preserved yet currently it faces problems due to its unstable structure. For example, some of the capitals are broken in many fragments and have to be replaced. A restoration plan was developed to consolidate the Hathor-Chapel without changing the character of the site or the building. Replicas made of a solid artificial stone can be used to replace the destroyed elements of the construction. Although these replicas can be distinguished by the material used, the fact that the shape is an exact geometrical copy of the original means that the impression of the ruin will be preserved. Again, a close-range triangulation scanner was used to generate a digital image of the building. In just four weeks a surface model of 900 million points was created. The acquired 3D data offers a spatial documentation of the construction before consolidation and also provides the necessary information for object duplication. Furthermore, ortho-photos of the digital image offer an ideal basis for two-dimensional architectural plans. They provide a time efficient way of drawing a highly decorated structure like the Hathor-Chapel.

The image is envisioned as a starting point for a future virtual reconstruction. Fragments of the building that are found during the excavation will be scanned and added to the 3D model. Missing

parts will be re-created in such a way as to distinguish existing remains and reconstruction ideas.

Conclusions

In using 3D modelling in archaeology and building archaeology, it is possible to distinguish two different types of digital models: the re-creation and the image. A re-creation is an abstract description and allows for analysis, understanding and visualisation if it is integrated into the working process. Therefore the finished re-creation is the result of a scientific investigation. By contrast, images are an exact geometrical representation of the original. As a working tool they offer a new type of objective three-dimensional geometrical documentation and therefore create an ideal basis for further investigation.

Both types of models offer potential for documentation and research. Which strategy best suits the aims of a given project must be decided by the scientist. Examples such as the investigation of the “Domus Severiana” and the excavation in Naga show that 3D models are more than just pretty – they are useful tools. Publishing only pretty pictures would be to neglect the real potential and scientific value of such a model and to waste the large amount of time and information which is bound into it. In future, such models should be accessible as references for further investigation, but an appropriate way to publish them has yet to be found.

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