The Art of Reconstruction

Documenting the process of 3D modeling: some preliminary results

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***Abstract*— The project 'The Art of Reconstruction' explores the usage of digital three-dimensional (3D) reconstructions to support research into historical and archaeological architectural settings. More specifically, the aim is to enhance the research on buildings that are nowadays partly or entirely lost, buildings that were once were keystones in the formation of local identities.**

Using 3D reconstructions during the research into built environments offers new insights and a new approach for analyzing data. The path that leads to the final reconstruction of the building should be documented and this documentation generates a vast amount of new data otherwise never encountered. This data should be stored in an interoperable database and combined with the results of the project published in an accessible format. The many perspectives on the actual building itself, i.e. the spatial context, and the possibility of visualizing the architectural phases through time, makes 3D modeling an innovative tool for the specialist. It offers a virtual world where various kinds of experiments can be conducted.

This paper will show some preliminary results of the digital 3D reconstruction of the lost Archaic temple of Caprifico di Torrecchia (Latium, Italy) that, when only described in words and drawings, would have remained invisible.

Keywords—digital reconstruction; 3D modeling; virtual archaeology; archaeological methodology; archaic temple

I. Introduction

'The Art of Reconstruction' is a one-year pilot-project that contributes to a 3/4D Research Lab at the Faculty of Humanities of the University of Amsterdam, consisting of a collaboration between digital specialists and researchers, that will offer 3D solutions and subsequent related databases for the Humanities. The objective is to create verifiable 3D models with the possibility of adding a time-element ("4D") to demonstrate transformations through time.

Reconstructing in 3D is a relatively new way to interpret archaeological and architectural data and has the potential to function as a source for filling in gaps in the archaeological record in a verifiable way. While creating the 3D reconstruction a variety of problems will present themselves: technical decisions concerning building techniques and how to reflect them in the model have to made; new questions concerning the material remains will arise and other reconstructions or (literary) sources have to be reconsidered. This approach to data is fundamentally and methodologically different than reconstruction in words or drawings. Using 3D modeling as a research tool, the specialist will be confronted with and forced to recognize problems that were otherwise not even apparent or perhaps had even been ignored. With this project we want to make a contribution to the development of a methodology for 3D modeling as a scientific research tool. To reach this, we closely follow the guidelines provided by the London Charter, an excellent organization that pleads for transparency and a methodology for digital visualizations in heritage [1].

As a case-study for the pilot-project the temple of Caprifico di Torrecchia was chosen because it had already been thoroughly studied, published and reconstructed with traditional illustrations. The temple was situated 60 kilometers south of Rome and founded about 520 BC, in a turbulent time when the legendary king Tarquinius Superbus reigned in Rome and threatened the region with aggressive expansionist politics. Many temples were built in this period, several received the same terracotta roof decoration produced in one workshop at Rome, as was the case with the temple of Caprifico [2],[3],[4],[5]. The temple stood only for a relatively brief period and was presumably destroyed shortly after 500 BC. The remnants of the temple remained preserved until the late 1960's when the terrain was leveled by the landowner. After this destruction, fragments the terracotta roof decoration were sold illegally on the art market, literally scattering the temple of Caprifico di Torrecchia all over the world. These fragments were traced, analyzed and published by an international team of specialists, which resulted in a nearly complete reconstruction of the terracotta roof[1].

II. The Process of Building: Some Preliminary Results

A. Additional research

When the modeling of the temple started with this 'nearly complete' reconstruction published in the Caprifico book as a starting point, immediately problems occurred. Some of the most indicative of these problems will be illustrated. The first 'problem' encountered, which was in fact a very first result,

[1] Initiated by Dr. Ann Brown in the 1970's, then conservator of the Ashmolean Museum at Oxford, which at the time had acquired some of these fragments. In 2009 the Ashmolean returned most of the fragments to Italy.

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was that the temple could not be reconstructed right away due to the lack of precise data. From the initial process of setting up the building details, it became clear that describing in words is not the same as visualizing it with a digital 3D reconstruction built stone by stone. We were confronted with problematic construction details never foreseen, not even by studying the original paper drawings, which seemed accurate and precise at the time. It became clear that these traditional reconstructions missed, avoided and sometimes even ignored details in construction techniques. In the case of the temple of Caprifico, the actual building, except for the roof system, was never fully investigated. Other 3D reconstructions that we thought were inspiring and useful to serve as parallels, proved to be unsound, as was noticed by consulting architects. Consequently additional research on Archaic and general building methods had to be carried out.

The additional research comprised of the study of ancient texts for descriptions of buildings as well as building techniques and epigraphic evidence (building inscriptions) for data on labor and building materials used. Also publications about building methods in Antiquity, as well modern works on contemporary woodworking, mud-brick building and roofing methods were investigated. Representations of ancient architecture in other forms like miniature votive temples, funerary architecture and wall paintings were re-examined too. Even modern pollen-analyses on vegetation in the Archaic period in the direct region of the Caprifico site proved to be very important in order to identify which kind of wood could have been used. Finally, other 3D reconstructions of temples have been analyzed and compared with reconstruction proposals for the temple of Caprifico.

B. Reconstructing a raking sima

Another example of an unforeseen problematic detail emerged while modeling the *raking simas*, the pan tiles that run along the edge of the pediment with a vertical plaque attached along one edge to divert rainwater off the roof [3] (p. l). There exist a number of 2D reconstructions of such frontal sides, but it became clear that because they were never tested by actually placing them on a temple, nor could they be studied from a random perspective, these reconstructions proved to be constructively illogical and even impossible (Fig. 1) [6]. The *raking simas* could not have been placed directly next to each other (where normal pan tiles overlap), but had to be interlocked in order to prevent rain from reaching the rafters below. Consequently, a technical solution had to be found in order to fit the *raking simas* on the roof and interconnect them with each other. This was achieved by partly inventing a interlocking system, and partially by conducting research into parallels from a new perspective (Fig. 2). It turned out that only one scholar gave true attention to *raking sima* construction, though Greek [7]. In Central Italy only one example of an interlocking system was found [8] (p. 48, fig 5.1 no. 15), unfortunately without information concerning what this reconstruction was based on. Re-examination of *raking simas* in museums in and around Rome showed many indications for interlocking systems. After this additional research the only solution seemed to be the addition of a projecting flange on the *raking sima* to overlap the next lower *sima* on the slope.

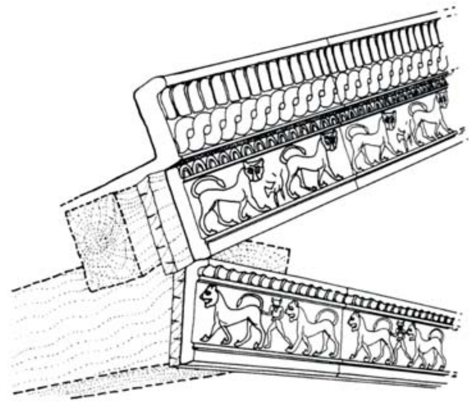

Fig. 1 2D Reconstruction of the pediment of the Regia in Rome. It does not show how the raking simas are attached to each other.

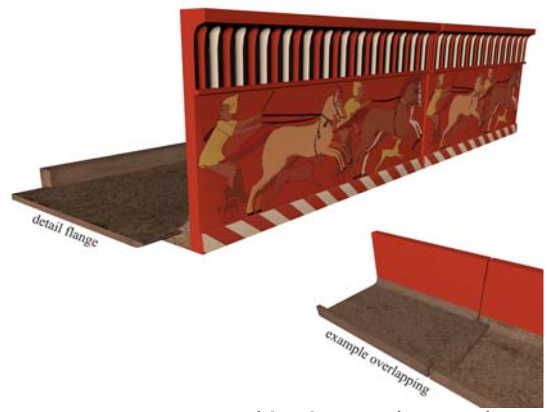

Fig. 2 3D Reconstruction of the raking sima from Caprifico.

C. Building a virtual temple roof

Reconstructing the roof did not appear to be as easy as it initially seemed. There are some clear indications for the dimensions of the various types of wooden beams that supported the roof, because of the presence of nail-holes in the revetment plaques (decorated terracotta plaques that protected the wooden structure of the temple). The location of those nail-holes reflect the dimensions of wooden beams such as respectively the rafters, battens and jack-rafters. But they do not reveal directly, for example, if the roof was supported by a truss or a post-and-lintel system (Fig. 3) [11] (p. 337, fig. 2).

The most stable solution would be a trussed roof (Fig. 4) [9]. However, other scholars prefer a post-and-lintel system. On what grounds? Indeed funerary architecture represents post-and-lintel roofs, but that is more suitable for house architecture or other smaller buildings with lighter roofs to carry. Of course it is tempting to look at the famous Greek temples with their post-and-lintel system roofs, but these temples are executed in stone and therefore require an entirely different way of building: because they are made of stone, they should be built high in order to carry the weight. Central Italic temples are typically low because they were made of wood which is lighter. Also the intercolumniation could be much wider when the truss is applied, because of its light construction and large span capability. A truss consists of two rafters joined at their ends to a tie-beam so as to form a triangle. The truss is so strong that its tie-beam can span great distances without any support, because it transfers the weight of the roof to the substructure. Post-and-lintel systems are very heavy and need to be supported by internal colonnades, which are absent in Central Italic sanctuaries[2]. For further discussion on the truss see Hodge [10], Klein [11] and Hopkins [12], [13]. Looking at Greek temples as parallels for Archaic Central Italic architecture confirmed that the types of post-and-lintel systems used in 3D reconstructions of other Central Italic wooden temples would certainly collapse because of the huge load upon the walls.

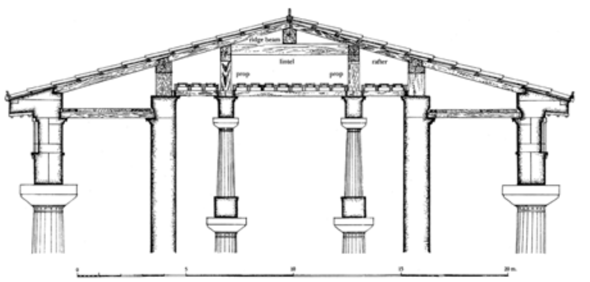

Fig. 3 Example of a Greek post-and-lintel system.

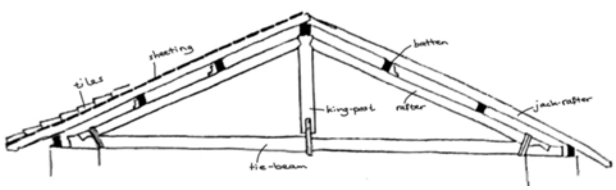

Fig. 4 Example of a truss.

While constructing the test-roof, it seemed logical that every pan tile had a supporting batten below. This assumption was confirmed after a closer re-examination of contemporary miniature votive temples. A post-and-lintel system does not require so many battens, but consists of a few bigger battens (*mutuli*). The jack-rafters on the battens should then project outwards as can be seen in the votive temples as well [14]. These jack-rafters had to be supported because of the huge weight of the roof tiles and terracotta decoration on top of it. As the protruding jack-rafters would certainly break under the weight of the extending pan-tiles, lateral *simas* and *acroteria*, it was necessary to take another look at the existing data but from a different point of view. The only remaining solution appeared to be to lengthen the tie-beams with supporting beams in between to attach the lateral revetments plaques, as the votive temple from Velletri [14] (Tav. XXXVIII and XXXIX) again, seems to show.

III. Construction a Virtual Building: The Workflow

Building virtually is comparable with building physically: one begins with modeling the foundation trenches, put the tufa blocks in it, impose the wooden timber-frame of the superstructure on it, bolster it with mud-bricks, calculate the intercolumniation, model the trusses, etc. Most of these objects or building blocks are modeled in Maxon Cinema 4D, a 3D modeling, animation and rendering application, and in some extent Meshlab, Autodesk 3DMAX and Google Sketchup have been used. The textures applied on the models were created and modified in Adobe Photoshop CS6. The individual objects are stored as Wavefront object files with a defined texture (resp. *.*obj* and *.*mtl*), Collada files (*.*dae*) and Cinema 4D files (*.*c4d*). The choice for saving the individual building blocks in different formats is due to the compatibility and the accessibility of the models in other software environments. For example, *.*obj* files are an open format and generally accepted in most modeling software where *.*c4d* files are only native to Cinema 4D. In addition the individual 3D objects are also placed into 3D-pdf files, this for providing easy access to the models by other scholars without the necessity for using complex 3D-modeling software.

Most of the models are built entirely by hand, exceptions being the models that are combined with the 3D scanned objects belonging to the original temple decoration. These models were scanned with a David SLS-1 structured light 3D scanner and processed with the bundled software. The use of a 3D scanner was mainly to explore the possible advantages over modeling manually. The addition of 3D scans, which are of actual size, accelerated the process of modeling specific parts of the roof decoration and contributed to a more genuine digital representation of the original object (Fig. 5). It is important here to mention however, that only a part of the original material is accessible for scanning due to the fact that most fragments are scattered all over the world in different museums and private collections. We only had access to the material exhibited in the communal museum of Cori in Italy.

The final 3D reconstruction will be presented within a model of the landscape limited to the immediate region of Caprifico. This model is derived from an isoline map [15] which has been digitalized and translated into a triangular irregular network (TIN-model) and converted to use in Cinema 4D in order to create a more truthful visual representation of the temple in its directly surrounding landscape.

IV. Documentation and Dissemination

To get the required insight into the process of reconstructing, it is necessary to document this process step by step. Therefore problems encountered, data used, decisions taken, the description of the individual building blocks, etc. have to be documented. These data are therefore collected in a database with the aim of creating a platform to make it possible to view, analyze and re-examine the reconstruction at every moment during the process of its building. The database

[2] Although the truss was invented in Greek Sicily in the course of the 6th century BC (Hodge 1960; Winter 1993, chapter 12) and then exported to mainland Greece and Italy. The idea of the truss was probably exported together with the terracotta decoration that was produced in Sicilian and Southern Italian workshops. A good example is the treasury of Gela in Olympia. It had terracotta decoration produced on Sicily and was proved by Hodge to have had a trussed roof.

management system used in this pilot project is Microsoft Access 2007 (*.accdb) with a database designed in accordance with the third normal form. This choice was made from a pragmatic point of view because of the accessibility, the relatively small scale of the project and the available options to export data in different formats. Objects and building phases belonging to the reconstruction are described individually and combined with all its assets in a transparent and structuralized way to provide the *paradata* behind the reconstruction. A reconstruction cannot be regarded a 'final' product, a science-based reconstruction, especially used as a research tool, must be 'open' to evaluation and reconsiderations and therefore be accompanied with data behind the reconstruction, i.e. the *paradata* [16], [17]. By creating *paradata*, it becomes possible to make adaptations or add new components to the reconstruction from every desired stage onwards, hence becoming a research tool for the interpretation of archaeological data.

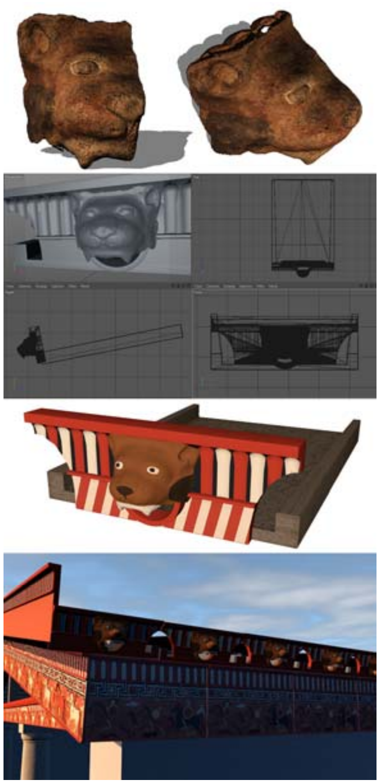

Fig. 5 From top to bottom: the combined scans of the lion-head waterspout; the lion-head scans imported in Cinema 4D and modeled; the rendered image of the spout integrated in its reconstruction of the lateral sima and lastly its incorporation in the 3D model of the temple.

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