

A Workflow for the 3D Reconstruction of a Late Antique Villa: The Case Study of the Villa Dei Vetti [†]

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Abstract: In recent years, 3D reconstruction has become an indispensable tool for archaeological research. 3D modeling software makes it possible to bring together and visualize different interpretative hypotheses simultaneously and to pose new questions that otherwise would not have emerged. The aim of this paper is to expose the process that, starting from the acquisition of the raw data, led to the volumetric reconstruction of a hexagonal-shaped building and a private bath belonging to the *pars urbana* of the villa of the Vetti, a Late Antique residential complex identified in the municipality of Capraia and Limite (Florence, Italy).

Keywords: 3D reconstruction; late antique villas; late antiquity; archaeology

1. Introduction

3D models are now widely used in archaeological research [1].

During the survey phases of archaeological evidence, photogrammetry turns out to be an inexpensive and accessible method; moreover, virtual reconstructions can be employed to try to understand the volumes of ancient spaces, supporting scientific research and promoting the fruition of cultural heritage by a non-expert public. The creation of 3D reconstructions of buildings involves the collection of heterogeneous data needed to understand the volumes of the rooms investigated and the construction techniques employed. For this reason, 3D models can be considered as valuable tools for rethinking old interpretations. Moreover, they make it possible to ask questions that, in an analysis carried out with traditional methods, would not have emerged.

The case study selected for this paper is the Villa of the Vetti, a Late Antique residential complex dating from the mid-4th century CE to the mid-6th century CE, located in the municipality of Capraia and Limite (Florence, Italy) [2,3]. The site, known since the 1980s, was investigated between 2010 and 2019 with archaeological excavations that allowed the identification of two structures of the *pars urbana*, service structures, and the remains of a structure that can be interpreted as a cistern for the water supply of the complex. The structures of the *pars urbana* consist of a building with a hexagonal plan, which can be interpreted as the representative sector of the complex, and a private bath, characterized by the *frigidarium-tepidarium-calidarium* pathway.

The objective of this research is the exposition of the reconstructive process that enabled the reconstruction of the volumes of the hexagonal hall and the private baths. Firstly, we will focus on the technical aspects of the work, namely the collection of the raw data, the methodology employed in the reconstructive process, and the digital tools used in the three-dimensional modeling operations. Afterward, we will expose the interpretive choices that led to the reconstruction of the two structures.

This study will not consider the decorative apparatuses, as their analysis would go beyond the objective proposed here.



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2. Methodological Approach

2.1. Data Collection

Surveys of the structures were made using a total station (Leica TCR400). The raw data were initially processed in AutoCAD, and then they were imported to QGIS. Here, the documentation was organized using the pyArchinit plug-in [4], which allowed the archaeological data to be connected to the surveys of the villa structures. In order to reconstruct the elevations of the hexagonal building, a dataset containing information on the plan and elevation dimensions of centrally planned buildings dating between the 1st and 6th centuries was created [5]. The creation of this dataset was crucial during the reconstructive phase as it provided a tool to organize the information in a more efficient way.

2.2. Reconstructive Methods

From a methodological point of view, the starting point of this study was the plan analysis of the buildings, which allowed the identification of plan dimensions based on multiples of the Roman foot (mostly multiples of 6 and 10 feet). Moreover, as is known from the precepts of ancient treatises, the relationships between different rooms in buildings were often governed by arithmetic and geometry. The former involved the use of simple proportions, such as 1:1, 1:2, 2:3, or 4:5, while geometry exploited irrational ratios ($\sqrt{2}$ and $\sqrt{3}$ were the most common) [6] (pp. 87–106). Geometry and arithmetic were the disciplines used to determine the plan conformation of the structure, while only arithmetic proportions were used for sizing elevations [7] (pp. 156–157).

Two types of data were used during the reconstructive process:

- The information that emerged from the archaeological excavation campaigns.
- The height measurement of ancient buildings that have been preserved with their original volumes.

The archaeological data were mainly used to identify the techniques used in the construction of the masonry or the type of roofing. Later, through the examination of comparisons available, it was possible to propose hypotheses about the volumetric of the elevations.

2.3. 3D Reconstruction

Normalized surveys of the site's masonry stratigraphic units (USM) were imported into Blender. The imported curves were converted into meshes, fitted with a surface, and extruded to the predetermined height. Once the modeling phase was finished, we moved on to the rendering phase, using the 3D modeling software Rhinoceros and the V-Ray plug-in. These images were created with the aim of improving the understanding of the archaeological context and highlighting the different material compositions that supposedly characterized the internal and external surfaces of the structures. However, the final product will not provide a photorealistic version of the residential complex but rather a schematic representation of the structures.

3. Reconstructive Choices

3.1. Hexagonal Building

The hexagonal building of the villa of the Vetti is characterized in plan by an inner hexagon with a diameter (measured between the vertices) of 50 Roman feet, around which there are five apsidal rooms. The diameter of the circumference that defines the entire structure externally presents a length of 100 Roman feet. The building thus presents a double hexagonal shell with a 2:1 proportional scheme, common for this type of construction [7] (pp. 146–147). Instead, in the apsidal rooms, a ratio of $\sqrt{3}$:2 between width and depth was used (Figure 1a).

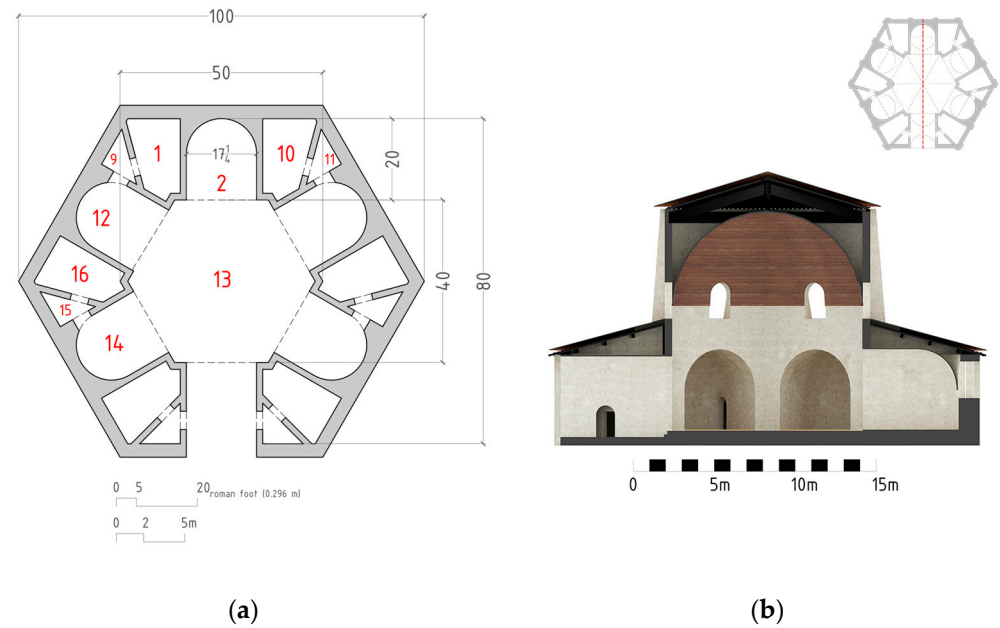


Figure 1. (a) Plan proportion of the hexagonal building; the numbers in red indicate the rooms that have been discovered; (b) Reconstructive hypothesis, north-south section.

The archaeological data collected supported the reconstructive process by providing the main information regarding the construction techniques used in the roofs of the rooms. In the central hexagonal room, numerous metal carpentry elements were found still attached to the charred wooden beams [2] (pp. 18–23). This type of finding is normally associated with wooden false ceilings [2] (p. 22), and for this reason, two reconstructive hypotheses have been proposed, one flat and one vaulted.

In the apsidal rooms, a cane-based vaulted ceiling similar to that described by Vitruvius has been hypothesized [8] (pp. 1033–1035). The triangular and trapezoidal rooms, on the other hand, must have had a flat ceiling, as evidenced by the discovery of fragments of painted plaster that were preserved in negative, flat imprints of canes [9] (pp. 123–125).

Through comparison with centrally planned buildings constructed between the 1st and the 6th centuries [5], analysis of static sustainability, and necessary lighting, three reconstructive hypotheses were developed:

- A There is a 1:1 ratio between the internal width and height of the central hexagonal hall, with a vaulted roof.
- B There is a 1:1 ratio between the internal width and height of the central hexagonal hall, with a flat roof.
- C There is a 5:4 ratio between the internal width and height of the central hexagonal hall, with a vaulted roof.

During the modeling phase, we chose to make only hypothesis A (Figure 1b), as it has height proportions that would have stressed the structure less. However, we consider the other two hypotheses, B and C.

3.2. Baths

Analysis of the plan measurements of the thermal sector allowed us to recognize a design based on multiples of 6, 10, and 16 Roman feet (Figure 2a).

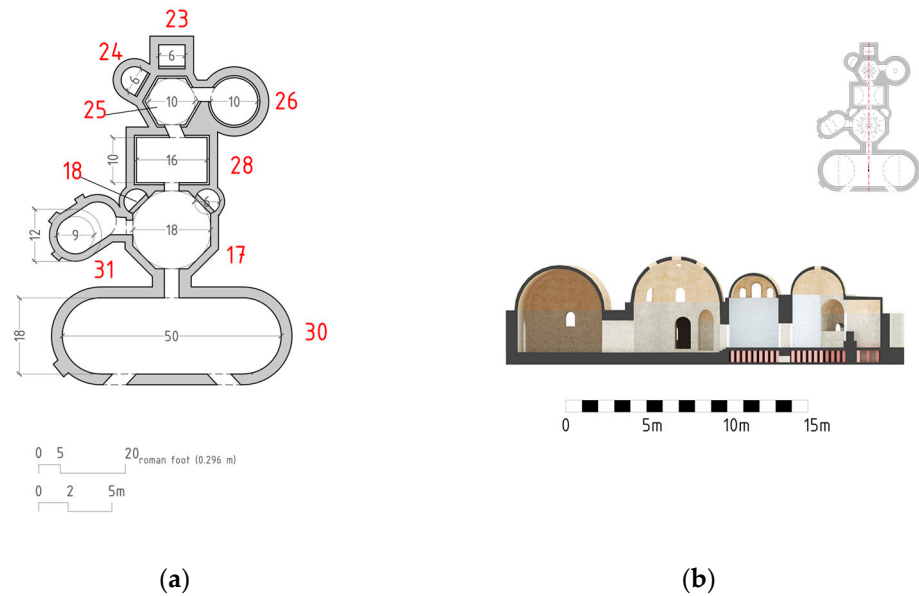


Figure 2. (a) Plan proportion of the baths; the numbers in red indicate the rooms that have been discovered; (b) Reconstructive hypothesis, north-south section.

The fragments of stucco found in room 24 during the 2017 excavation campaign are the only finding related to the roofs of the rooms and testify to the presence of strangulated vaults, which served to channel the condensation caused by the steam that formed in the hot rooms towards the edges of the room, preventing dripping [3] (pp. 93–94).

The types of roofing were chosen considering the layout of the rooms in the baths. A domed roof was chosen for the circular *laconicum*; pavilion vault was used for the polygonal rooms; a barrel vault, which is quite common for this type of plan conformation, was preferred for the rectangular rooms [10] (p. 124); semi-domes were chosen for the semi-circular basins and curvilinear niches [11] (p. 119).

The starting point for reconstructing the height proportions was an indication from Vitruvius regarding the sizing of *laconica*. The height of the other rooms was then determined in order to ensure proper illumination of the surrounding spaces. A logical and consecutive line of reasoning was then followed in order to reconstruct the interior of the baths (Figure 2b).

4. Conclusions

These initial reconstructive hypotheses have made it possible to evaluate these rooms by analyzing their ancient volumes. New investigations will certainly yield new data, which may support or refute these reconstructive hypotheses. Moreover, this work did not include the reconstruction of the decorative apparatus; therefore, in the future, it may stand as a starting point for the study of the interior and exterior decorations of the complex.

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Conflicts of Interest: The author declares no conflict of interest.

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