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A digital reconstruction of the sunken “Villa con ingresso a protiro” in the underwater archaeological site of Baiae

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Abstract. The Underwater Cultural Heritage represents a key aspect of our historical memory still little known due to a number of limitations imposed by the underwater environment. The aim of this paper is to explore the use of digital three-dimensional reconstructions to support the research about this immeasurable archaeological and historical resource. The whole virtual reconstruction process is described step by step, focusing on the iterative feedback allowing for reaching the best virtual reconstruction solutions, helping the archaeologists to better focus their reasoning through a detailed visual representation, and the technical experts to avoid misleading details in the final virtual reconstruction.

1. Introduction

The Underwater Cultural Heritage (UCH) is an immeasurable archaeological and historical resource, with extensive and varied assets (sunken cities, ancient shipwrecks, prehistoric submerged landscapes), but it cannot be easily accessible by humans due to a number of limitations imposed by the underwater environment. As a result, it is quite evident how Computers graphics techniques like 3D Reconstruction, Virtual (VR) and Augmented (AR) Reality are a still underrated way to leverage the enormous potential of the UCH. In fact, these technologies can be efficiently applied in this field in order to improve, as much as possible, the accessibility of the UCH to the public without any constraint given by distance or time.

Today, optical and acoustic surveys are the main acquisition techniques to obtain a 3D representation of underwater archaeological sites and the related remains. Such information is traditionally used in order to have an accurate documentation of the status of the site. In particular, these high-resolution data represent a valuable source of information for interpreting architectural structures with a great level of detail.

An accurate 3D representation can be also used as the starting point for creating a scientifically sound virtual reconstruction of the site, embedding historical information coming from different sources. It can



be useful for a careful interpretation of the existing archaeological remains but sometimes they might also be capable to suggest new archeological discoveries.

In this paper, we present the results obtained from the virtual reconstruction of the complex of the “Villa con ingresso a protiro - Villa with Vestibule” dated to the first half of the II century AD, Hadrian Emperor era, located in the Marine Protected Area - Underwater Park of Baiae (Naples). The applied method exploits the high-resolution data acquired by using the latest techniques for the construction of acoustic microbathymetric maps together with drawings and other historical and archaeological information to build a suggestive 3D digital reconstruction of underwater architectures not anymore existing. It is based on an iterative feedback that allows for reaching the best reconstruction results, helping the archaeologists to better focus their reasoning through a detailed visual representation, and the technical experts to avoid misleading details in the final virtual model. This workflow involves several professional figures, such as 3D graphic designers, archaeologists, and art historians.

2. Methodology

The reconstructive workflow (from fieldwork to the virtual reconstruction) was carried out taking into account the results of the theoretical and methodological discussion built around the definition of Virtual archaeology [1]. In fact, in the last years, a lot of efforts have been spent in defining guidelines for the implementation of methods to construct virtual interpretations, in specific documents such as the London Charter [2] and the Principle of Seville [3] with the aim of supporting and promoting interpretation and simulation based on a theoretical and multidisciplinary scientific approach.

The main steps of the proposed methodology are shown in Figure 1:

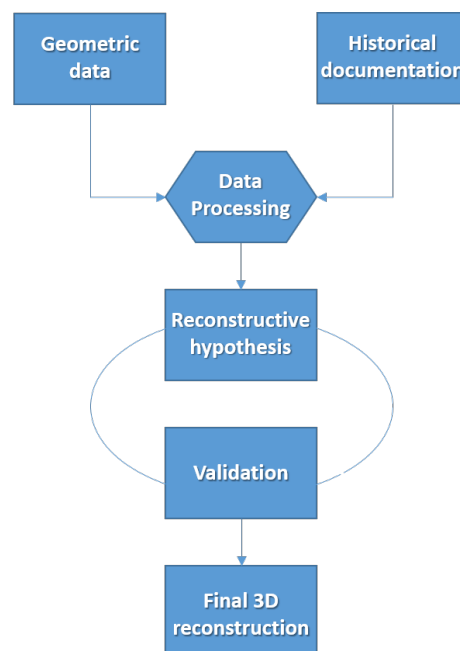


Figure 1. Iterative feedback reconstruction process based on the integration of 3D data and historical analysis.

The first stage of the process is the data collection. It is focused on the acquisition of historical documentation, scientific literature and geometric data gathered during the survey campaign. The aim is to collect all the information needed to create a hypothetical reconstruction of the archaeological remains with a high level of consistency.

Subsequently, all the acquired data (archaeological maps, illustrations, photos, Digital Terrain Model, etc.) are analyzed and put in relation. Several experts have to be involved in order to discuss

different interpretation hypotheses. The discussion is supported by the employment of a 3D platform capable of merging the 3D reconstruction and the acquired model in the same 3D space.

The last steps of the process consist of modeling the architectural remains and validating it in line with the interpretation process. The approach is based on interleaving a phase of technical reconstruction with a strong critical revision in order to generate a feedback process, iterating the construction/correction loop as much as needed. Finally, in order to map the evolution of the virtual interpretation, several 3D layers are saved together with the final model, examined and approved by the scientific experts.

3. Historical documentation

3.1. *The underwater archaeological park of Baiae*

Baiae was a famous coastal settlement in the volcanic Phlegraean Fields, much appreciated by the Roman aristocracy since the Late Republic (II-I century BC). The thermal waters and the climate favored the development of a monumental and residential architecture which was improved by the Emperors during the following centuries (I-IV AD). At the end of the fourth century, beginning of the fifth century AD, several ground movements (bradyseism) caused the sinking of a portion of the city below the sea level. Many luxurious villas built in Baiae and a large part of the town, became Emperor's property under Augustus and his successors (such as Julius Caesar, Augustus, Pompeius the Great, Marcus Antonius, Caligula, Nero, Hadrian, *Septimius Severus* and the list goes on).

Even after the decline of the Roman Empire, the baths of Baiae continued to be used by the Visigoths, Vandals and Gots. The historian Cassiodorus in the sixth century affirm that Baiae is still a pleasant resort. However, the settlement was devastated by Muslim raiders in the VIII century AD.

Baiae overcame the crisis and in the Middle Ages, it was still famous for its thermal waters. We know for example that the Swabian King Friedric II 7 frequented its thermal waters in 1227 and restored some facilities. The importance of the port of Baiae in the fifteenth century is well highlighted by the construction of the castle and of the coastal defense systems by the Aragonese.

In the following centuries Baiae continued to be a frequented center and, with alternating vicissitudes also due to the seismic nature of the territory, remained a center of attraction and the charm of its ruins made it one of the favorite destination by travelers from all over Europe up to our days.

Nowadays, most of the buildings of the city lie on the bottom of the sea covering an area of about 177 hectares that since 2002 has been declared a Marine Protected Area. The scuba divers can visit several underwater paths : 1) the Nymphaeum of Claudius lying off Punta Epitaffio with the copies of the original statues, now exposed in the Phlegraean Fields Museum; 2) the remains of the Villa dei Pisoni, with the spectacular architectural changes due to emperor Hadrian; 3) the remains of houses and storehouses of Portus Iulius; 4) the "Villa con ingresso a protiro – (Villa with Vestibule)", that is the subject of this paper, siding a road along which there were *thermae*, *tabernae*, and other buildings.

3.2. *The "Villa con ingresso a protiro"*

The "Villa con ingresso a protiro" (Figure 2) has two clearly defined areas, the residential quarters with the garden (the squared area in the centre of Figure 1) and the baths on the left side of the garden.

Two red-plastered masonry benches - framed by stucco pilasters - marked out the threshold along the road. The name '*prothyrum*' comes from the presence of two stuccoed columns – no longer existing – that were edging two short parting walls built on the sides of the threshold.

The vestibule, with doorways to the '*ostiarius* quarters' (gatekeeper's lodge), led to the *atrium* with *impluvium* in the center, whose walls were decorated in the lower part with marble slabs (Tenaro's red marble fragments were recovered during underwater surveys). Also the walls of the adjacent rooms were decorated with marble, many of which had mosaic flooring. A mosaic floor in black and white *tesserae* with geometrical motifs (hexagons and pseudo-emblems with circles and *peltae*) is positioned in a room at the north-eastern corner of the *atrium*.



Figure 2. Archaeological map of “Villa con ingresso a protiro”.

This mosaic, classified by ISCR as n. VIP 19, lies inside a rectangular area measuring 4.77 metres by 5.55 metres in the northwestern part of the Villa. It consists of a background of white tesserae, with the ornamental motifs bordered by a double line of black tesserae. The principal geometrical design is a series of hexagons covering the whole floor, with a small square of four black tesserae at the centre of each hexagon. Black tesserae also make up the double border at the edges. The central section is a pseudo-emblema consisting of four circles inside a large square. Each circle contains four peltae and a central quincunx (the five-spot motif on six-sided dice). There are three equidistant solid black equilateral triangles outside the circles on each of the inside edges of the square. The point of each pelta terminates in a small flower with three heart-shaped petals separated by a central dot. The central space between the four circles contains a small square enclosing a cruciform floral motif with a central dot. The floral motif has lobed petals with arrowhead tips. The mosaic dates back to the second century AD [4, 5].

A large hall with a 10.37-metre wide apse lies to the South of the atrium (a nymphaeum?). This was probably not part of the original design but at the moment it is impossible to establish the date of construction and its relation with it. Its general appearance, and in particular the sumptuous large-scale marble panelling, is reminiscent of the grand halls of the Late-Imperial domus of Ostia.

In 1992, in the garden of the Villa, a statue similar in style to the Aphrodite of the Gardens by the Greek artist Alcamenes, was recovered and is now housed in the Archaeological Museum of Campi Flegrei.

The first archaeological documentation of the Villa was done in the second half of the 1980s, thanks to a group of advocationalists that produced the extended survey and mapping of the archaeological remains of Submerged Baiae [6-11].

Then, several rooms of the Villa were documented and restored in the frame of the ISCR “Restoring Underwater” Project, funded by the Ministry of Cultural Heritage and Activities and Tourism. This project, designed by the archaeologist Roberto Petriaggi, started in 2001 with the conservation of three fishponds of the Roman Villa of Torre Astura (Nettuno-Rome), then moved to Baiae in 2003 and it is on course. It is dedicated to testing methodologies and tools for documenting, conserving and valorizing *in situ* the underwater cultural heritage [12-14].

The “Restoring Underwater” Project took care of the Villa con ingresso a protiro for the first time in 2003, when Roberto Petriaggi directed the restoration of a room with a white mosaic floor measuring around 4.5 metres long and 2.5 metres wide (classified as n. 14 by ISCR) [15]. Then, in 2010 a thermal room (caldarium) were restored under the direction of Roberto Petriaggi [16].

In 2012 started another campaign of 3D documentation [17-19] and conservation under the direction of Barbara Davidde Petriaggi, with the restoration of some sectors of the archaeological complex and in particular the room paved with the black and white mosaic floor (Figure 3).

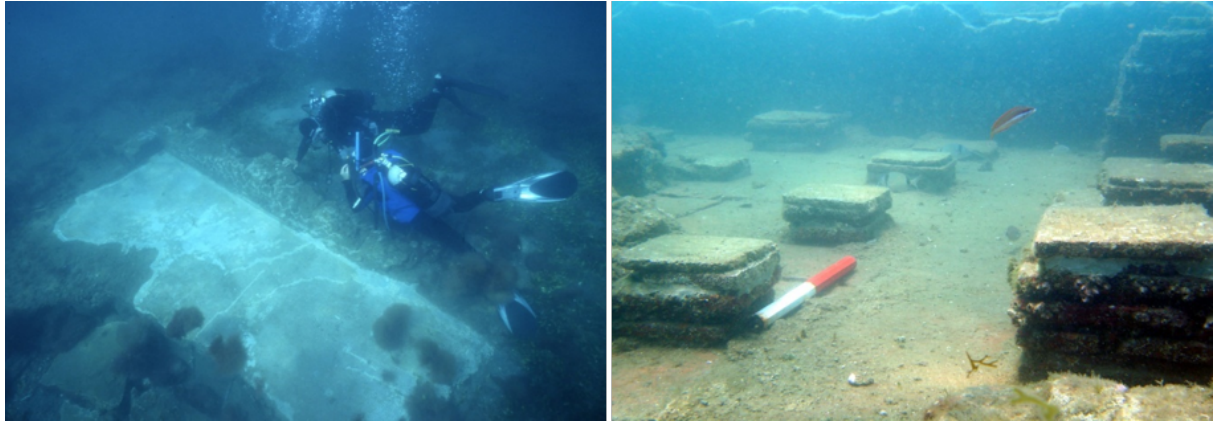


Figure 3. ISCR restoration activities in the “Villa con ingresso a protiro”.

The DTM of the underwater archaeological site has been obtained through a morpho-bathymetric survey carried out by the Institute for Coastal Marine Environment (IAMC) of the Italian National Research Council (CNR) [20]. The DTM of the seafloor allowed to draw the main archaeological features of the area, that also include the military complex of Portus Iulius and the ancient thermal and villa complex of Baianus Lacus. The extraction of archaeological features from DTM has achieved thanks to the use of a GIS-derived tool based on the profile curvature algorithm.

4. Source-based 3D modeling

The sources for the virtual reconstruction of the “Villa con ingresso a protiro” were the manual and 3D graphics documentation, digital photo made by ISCR during the conservation campaigns and the acoustic bathymetry provided by IAMC.

To improve the understanding of the underwater architectural complex by the underwater and non-underwater visitors, given the poor conservation of ancient submerged structures, it was necessary to hypothesize much more than the structures relieved *in situ*. A three-dimensional hypothetical reconstruction based on archaeological evidence has been realized and, for what has not been preserved, reconstructions have been proposed on the coeval examples known from the archaeological research and literature.

4.1. Volumetric model

Once all the needed information about the villa has been acquired and processed, it is possible to start the modelling task. At the beginning, a volumetric model has been created showing the walls of the main structure. It has been developed using as reference the acoustic DTM and the archaeological map. In particular, the archaeological map, has been used as constraint to verify the correct scale of the model. Contrary to other known roman villas, the “Villa con ingresso a protiro” has not a canonical shape. In fact, its shape was conditioned on the front by the presence of the road, while in the back by the line of the coast. The main entrance is opened on the west side of the atrium and it is not perfectly in axe with the impluvium basin. Usually, in the Roman Villas, on the opposite side of the entrance there was the tablinium, a richly decorated room where the *pater familias* used to receive his *clientes* and from where

it was possible to enter the garden. Instead, in this Villa, the entrance to the garden is an open passage in the north side of the hall's wall.

Moreover, the most part of Roman villas has a garden, surrounded by a 4 or 3-sided column portico; in this villa, until now, we have found traces of columns only on the South side. Nevertheless, in the reconstruction hypothesis, we suggest to build the portico on the whole perimeter of the garden, but it is a hypothesis that we hope will be confirmed by future archaeological excavations.

On the right side of the hall, there is the large hall with a wide apse that we could hypothetically identify as a nymphaeum. As at the moment, the relation with the original design of the villa and this room is unknown, we did not include it in the 3D hypothesis. We will consider adding this room in some future update as its function and dating will be more clear and sure.

4.2. Architectural model

In order to build the architectural model, we have added on the conceptual model structure details like roofs, columns, doors and windows, referring to the images and documents collected during the data acquisition task, and taking as an example the Roman villas dated at the Second Century AD [21, 22] (Figure 4). The archaeological reconstruction of the roof covering, of the wall paintings and of the furnishings as of the garden, are purely hypothetical because no traces of these archaeological data have been documented underwater. In fact, the remains of the walls of the Villa are almost completely disappeared. For example, the room paved with the mosaic floor n. 19 has the perimeter walls measuring about 5-10 cm high, along the seaward sides to the south and the east while the walls in the northern and western side measure about 50 cm in height (Figure 5).



Figure 4. Architectural model of the “Villa con ingresso a protiro”

5. Conclusion

This paper describes a process of acquisition and modeling applied to create a virtual reconstruction of the complex of the “Villa con ingresso a protiro - Villa with Vestibule” dated around the II century AD, located in the Marine Protected Area - Underwater Park of Baiae (Naples).

A commonly used 3D acquisition and modeling approach along with some different topics are discussed, suggesting both optimized procedures for data processing and communication. In particular, as synthesized in Figure 1, an iterative methodology is suggested to support the interpretative modeling

step, simplifying the feedback on virtual models by the archeologists. This solution gives a significant improvement on the complex procedure for reconstructing in 3D archaeological structures whose remains are often very few with respect to its original shape. In this way both an instrument of communication and valorization of the cultural heritage site is provided, helping the interpretation of archeological and architectural ruins.

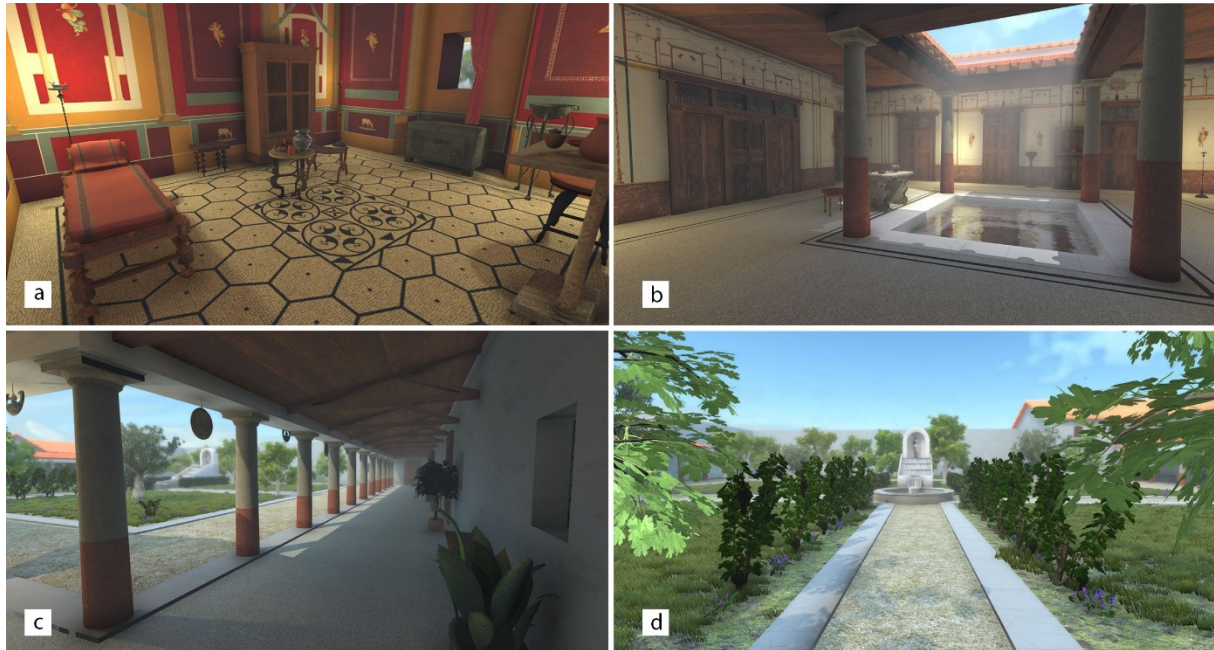


Figure 5. Images representing different portions of the Villa: a) room with pelte mosaic; b) atrium with impluvium; c) peristilium; d) garden.

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