The boiler room of the Small Baths in Hadrian's villa

Excavation, analysis, preservation

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Abstract: The excavation of the boiler room in the Small Baths of the Hadrian's Villa in Tivoli, made in 2009, allowed for the first time the analysis of the baths' "engine"

The discovery of a large furnace and the analysis of the traces left by the metallic elements, now absent, have enabled it to get light on technological solutions, relating to heating rooms and water management of the complex.

The graphic documentation was been carried out with laserscan technology: a first survey was made in 2004, during the general planning of the building; the second one was made after the excavation, aimed at studying the environment. A subsequent photo campaign was designed to have a database of the chromatic and material database of the excavation.

The postprocessing operations, in this case, were aimed to obtain a tridimensional model that, while maintaining the original detailed features, was easy to manage and exportable in the web.

Keywords: Small Baths, Hadrian's Villa, Laser scanner, fisheye correction, Unity.

The boiler room in the Small Baths of Hadrian's Villa

Excavation and analysis

The work presented here stems from the collaboration started in 2004 in Hadrian's Villa during a Master of Architecture and Archaeology organized by the University Politecnico di Milano[1].

The approach and the study of the same ancient building using different methodologies not only enriches the knowledge, but, year after year, seems to bring more near doctrines only in appearance quite distinct.

The Small Baths in Hadrian's Villa, both for the excellent state of preservation and for the architectural

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[1] This paper is the result of research carried out jointly by the authors; only in the writing, the paragraph about excavation is made by Alessandro Blanco, those about the survey, the elaboration data, the texturing and the exporting in Unity by Mirco Pucci. We would like to thank prof. P.F. Caliari, director of the Master and promoter of the excavations that, since 2007, are accomplished in the Small Baths; prof. G. Verdiani, rensponsible of the surveys; dr. B. Adembri, director of the villa for the Soprintendenza per i Beni Archeologici del Lazio.

solutions "so innovating that, with the same clarity, probably were never carried out"[2] is of course one of the places designated for this kind of activity.

The aim of this work is not only to present briefly the results of an excavation carried out in the boiler room, but also to indicate the procedures used, in the next phases of survey and postprocessing, to make more light and manageable the original pointcloud, allowing to obtain a three-dimensional model consultable easily on the web. This process, certainly desirable for the cultural heritage, not only facilitates the accessibility to scholars to information gathered, organized in databases, but can have also different applications, from research to tourism.

The Small Baths in the Hadrian's Villa shows, in the thermal path, a careful organization of the space reserved for the emperor and those reserved to the servants.

The main entrance was located North: this side was occupied in the center by a nymph, divided into two exedras and three rectangular niches, the sides of which there were two entrances. The eastern gave access to a courtyard with a porch used as a gym, the western allowed to reach the dressing room and gave access to the inside of the baths.

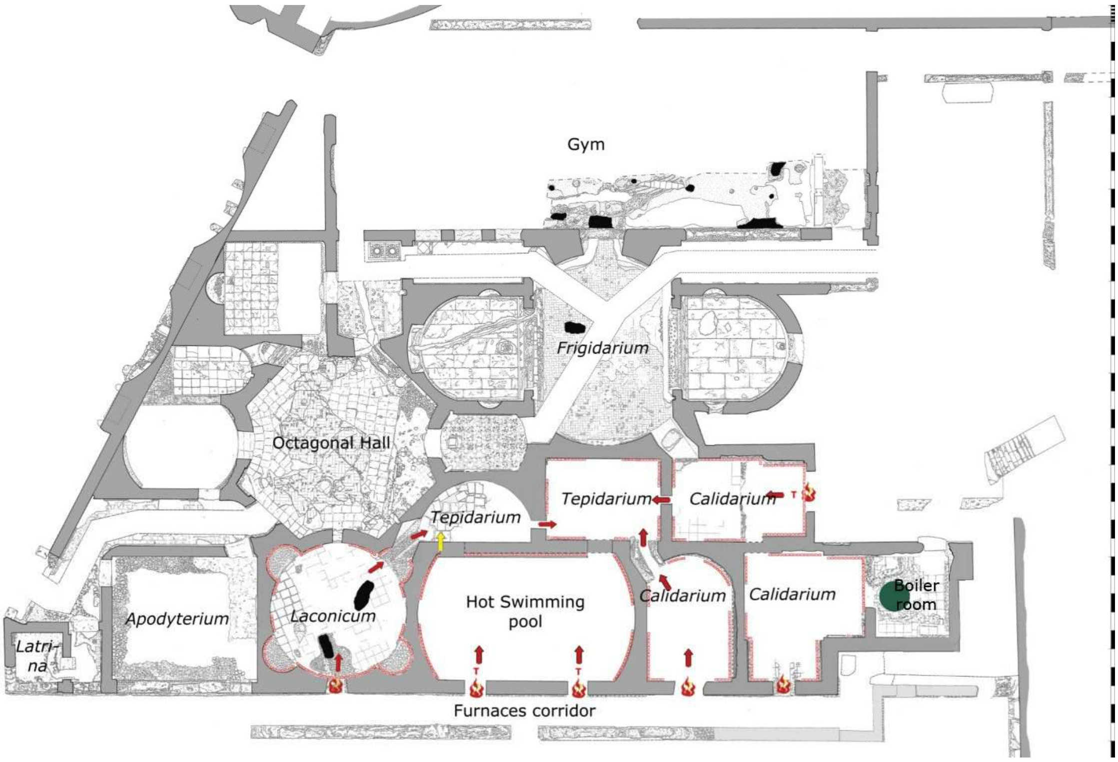

Fig.1 – The plan of the Small Baths with the heating system

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[2] C.F. Giuliani, La Villa Adriana, in Adriano. Architettura e Progetto, Milano 2000, p. 55.

As already suggests the orientation, the nymph was certainly pre-existent, originally built as architectural background in the garden near the Building with Three Exedrae[3]: so, in a first time, it hid the Small Baths during the construction; subsequently, when the building was completed, its nature was perfectly suited as entrance front to a bath.
Within the complex, an octagonal room, with alternating straight and convex sides, allows sorting pathways between hot rooms, cold rooms and the gym.
The heated rooms, in particular, are arranged along the west side of the building, to receive a better insulation: a circular sudatio, a large heated swimming pool and two calidaria are recognizable. Two tepidaria intermediate between hot and cold rooms are heated indirectly and make more softly the switching from the first to the others. In front of the front straight, at a lower altitude, originally ran the corridor of the furnaces that warmed the baths.

Fig. 2 – The boiler room after the excavation

[3] G.E. Cinque, E. Lazzeri, *Analisi geometriche e progettuali in alcuni edifici di Villa Adriana*, in *Romula* 2010, pp. 67-8. The authors consider the nymph later: it is not clear why, in a second phase, it should have been made an oblique nymph, cutting and making unusable different rooms, however the ancient building techniques show the opposite. The rear wall of the nymph has a continuous facing in *opus reticulatum*, clear evidence that there were no walls behind it when it was realized; the walls of the baths, moreover, are not cut from its construction but lean against it.

At the bottom of this, in the SW corner, there was a square room of 4.00 x 4.40 m (fig. 2), which originally held the heart of the water heating system, the large boiler (diameter of about 2.20; height conceivable 2.50 - 3.00 m). A door located on the east allowed the servants to reach the underground corridors of the Grande Vestibolo within which was crowded, very probably, the wood needed for the functioning of the complex. A second door, located in S side, seems to have been closed coarsely under construction.
The room, excavated in September 2009, was originally buried to 1.30 m in height and held an inhomogeneous stratigraphy. The upper layers had numerous marble fragments, apparently not relevant to this room (which was simply plastered) but coming from the decoration of the nearby noble halls (fig. 3). These layers testify probably the ground displacement happened in the Hadrian's villa or in the Middle Ages, caused by the search for building materials, or in the modern era, aimed at search for valuable materials. The underlying layers were related to the last period of usage of the furnace, with different layers of ash, more consisting above the original paving in bricks (fig. 4).
The inside of the room is almost entirely occupied by the powerful base of the boiler, removed in the Middle Ages: the furnace below, besides the boiler, heated, through an arched passage, also the near calidarium (fig. 5). This was equipped, in fact, with a hypocaust (i.e. a floor suspended on pillars between which circulating the hot air that warmed the room). On the eastern side there is a small staircase that allowed the servants to operate the complex system of water-taps: the service staff, in fact, had to deal with the mixing of the water used in the three pools of the two neighboring calidaria and, probably, also in the large heated swimming pool.

Fig. 3: The marble decoration found inside the room

Fig. 4: the layers of ashes

To reconstruct the complex system of pipes and valves is now particularly complicated: while the pipes serving the frigidarium ran under the floors and, even if after the pipes were removed, their course is now understandable, to reconstruct the piping system between the boiler and the pools is more difficult, because the pipes ran mainly along the walls, often supported only by few nails (fig. 6).

The basement of the boiler still has the traces of the four vertical brackets that anchored the boiler to the basement; a horizontal hollow housed probably a metal bar that prevented the bending of the bottom of the boiler (fig. 5).

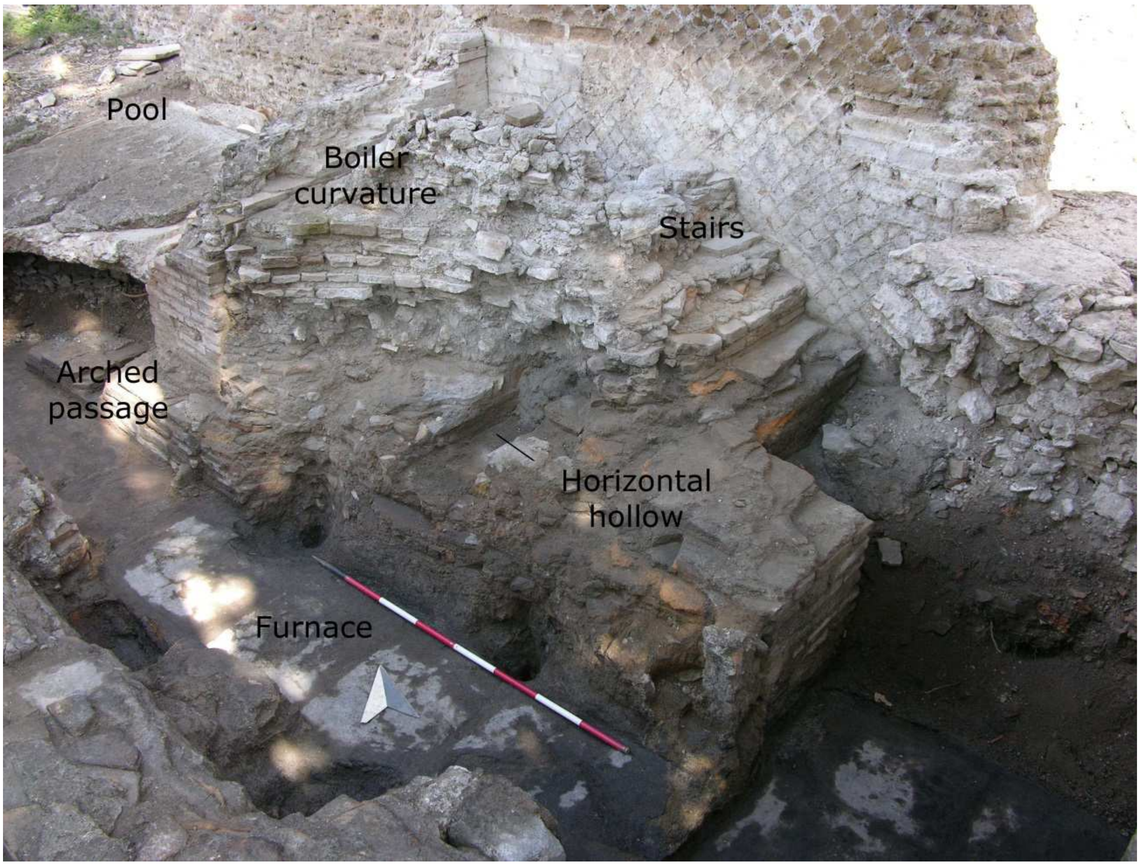

Fig. 5 – The peculiarities that characterize the room

The water heating system was also ensured by a semi-cylindrical element, generally made of bronze, called testudo alvei, originally embedded in the walls (figs. 7-8): this container, suspended above the fire beside the boiler, became hot and, being open on one side towards the pool, let that the water was heated flowing inside.

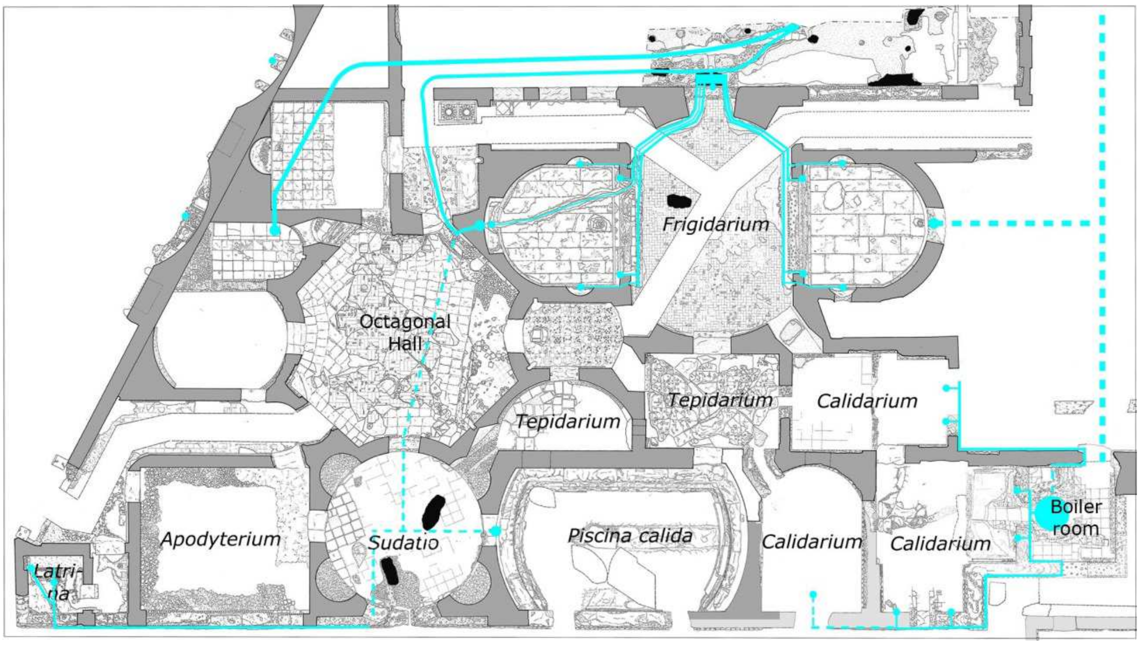

Fig. 6 – The original piping system

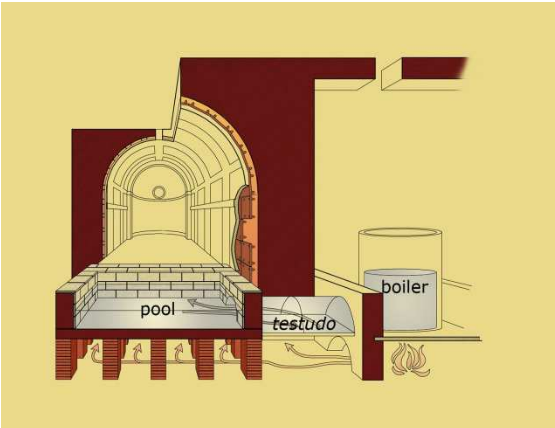

Fig. 7-8 – The testudo in a reconstruction and in the Suburban Baths in Herculaneum

In this case the testudo was removed, but the traces left by the lead nailed sheet remain in the lower face of the floor of the pool and the print left by of the pipe (connected to the testudo) which allowed the emptying of the pool (figs. 9 and 10).

The original aspect of this system is well preserved in few sites, as the Suburban Baths at Herculaneum, where the pool of the calidarium, still covered with marble, presented the testudo alvei and the adduction pipe (fig. 8).

Fig. 9 – traces left by the lead nailed sheet

Fig. 10 – the pipe connected to the *testudo*

The survey of the boiler room

Several surveys were made of the Small Baths, from 2007 with the survey of the octagonal room, to 2008 with all the interior of this building and 2009 with the exterior parts of the baths.

The digital survey of the boiler room was made in 2009 with a phase shift laserscanner Faro Photon 120 with a Nikon D200 digital SLR camera mounting a Nikkor 10mm fisheye lens on the top.

Actually this area is earth covered for preservate the structures and the contiguous areas.

It was necessary to place it on seven different station points (fig. 11), because the morphology of this site is very particular, with different heights of the floor. The use of spherical targets made more easy the successive phase of clouds referencing. The laserscanner campaign was finished acquiring more than 45.000.000 of points and taking 70 photos (10 for each station).

It's very important that is possible to unify the data of this digital survey of the boiler room with the other survey made in the past at this building, so we have a more complete and upgradable database of the cultural heritage.

Fig. 11 – The full pointcloud of the boiler room with in red the seven scanstations

The elaboration data and the 3d model

After the merging of the various scans it's possible to export a pointcloud to generate a 3d model. The aim was to produce a light and easy to use 3d model, but at the same time It must be characterized by a high level of accuracy in its geometrical parts: so It was necessary to apply an image-based methodology, with the use of a group of normal maps generated with a baking process from the hipoly model to the low poly model4.

After filtering and optimizing the pointcloud, a hipoly model (about 1.000.000 of triangular polygons) was generated: this mesh is necessary to use as reference in the baking.

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[4] G. Verdiani, S. Di Tondo, F. Fantini, M. Pucci, *Il ritorno all'immagine, nuove procedure image based per il Cultural Heritage*, in *LULU* 2011. The authors describe this methodology.

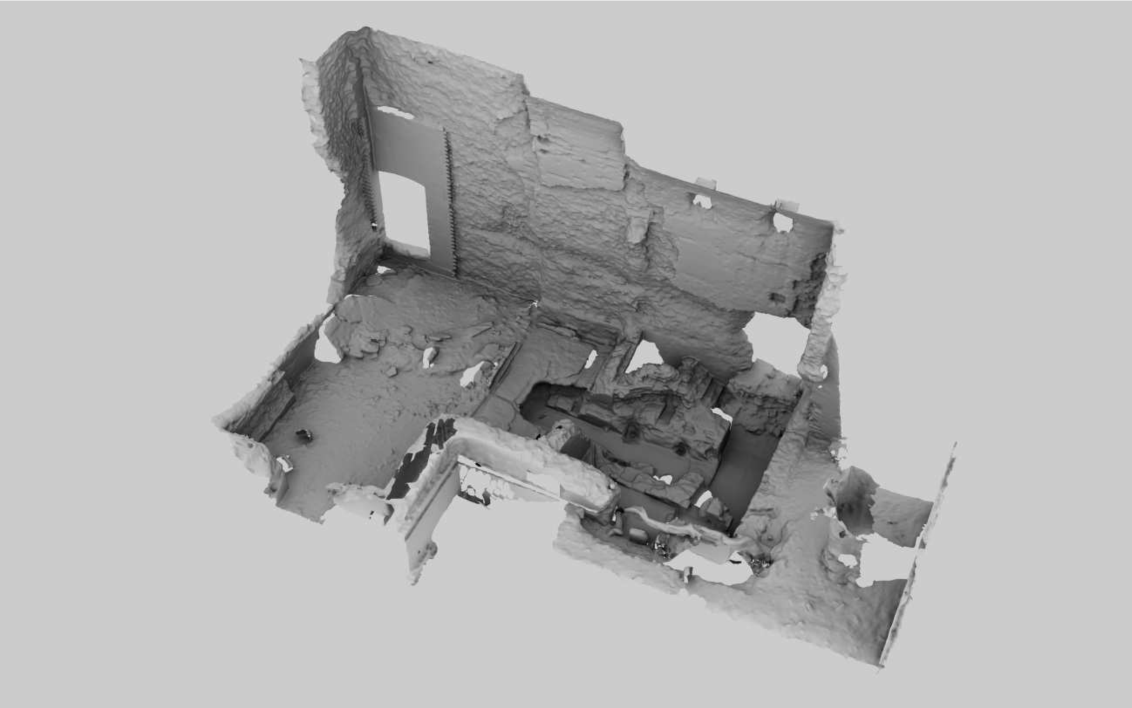


Fig. 12 – the hi poly 3d model (about 1.000.000 polygons)

Then, with a decimate operation, a second model was created (about 34.000 triangular polygons), and this model would be the basis for the optimized 3d model aimed to multimedia presentation.
Now it’s necessary to realize an optimized low poly mesh, with minimal modeling operation and filling the various holes existing in the mesh.
The UV map of the low poly 3d model was made with an unwrapping operation, and this map is necessary for the subsequent application of the normal map and colour map.
This map allows a bijective correspondence between the three-dimensional surface and the texture (Fig. 14), in this way a mesh can bring along information via a bitmap applied to this map.
The UV map must be as continuous as possible and doesn’t have cases of overlapping, in this way there is a good readability of textures to apply.
With an operation of baking is generated the normal map (this is an RGB map that codify in every pixel the normal of the hipoly mesh).
This map allows to add geometrical characteristics of a low poly mesh, virtually increasing the number of polygons. So the model of 34.000 polygons is fully edited and with the normal map has a good geometrical accuracy but it remains a easy to use model, manageable on with every hardware.

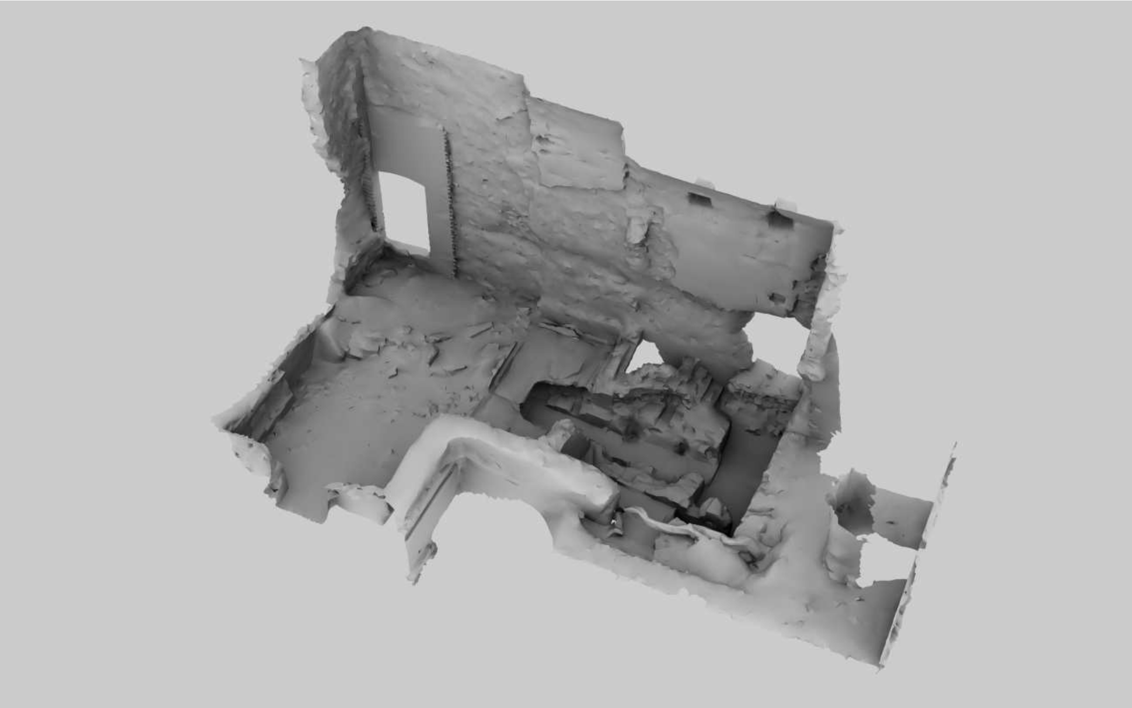


Fig. 13 – the low poly 3d model (about 34.000 polygons)

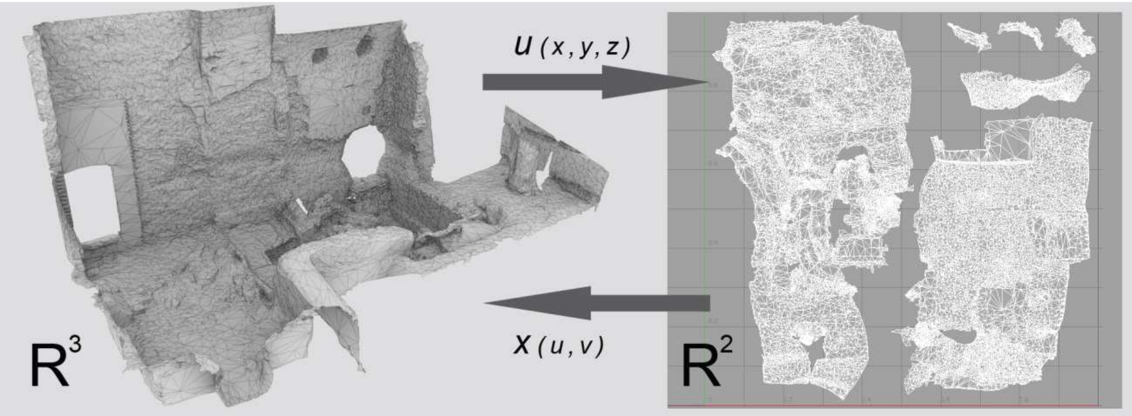
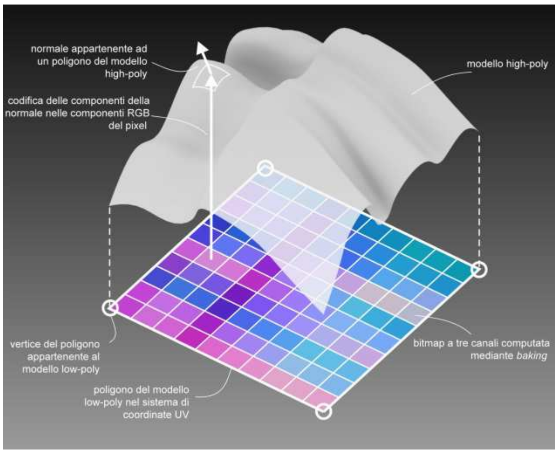
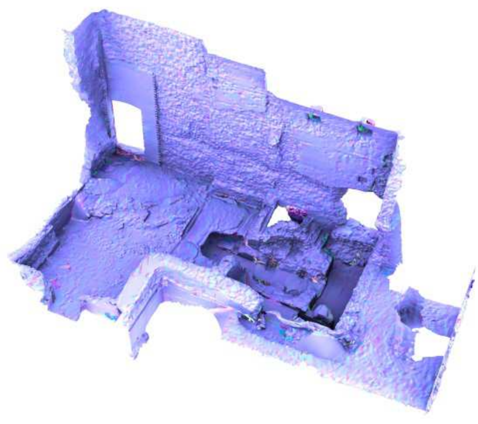


Fig. 14 – the UV map





Figs. 15-16 – the normal map

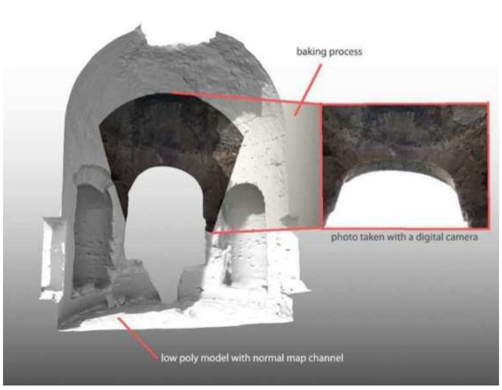
The texturing

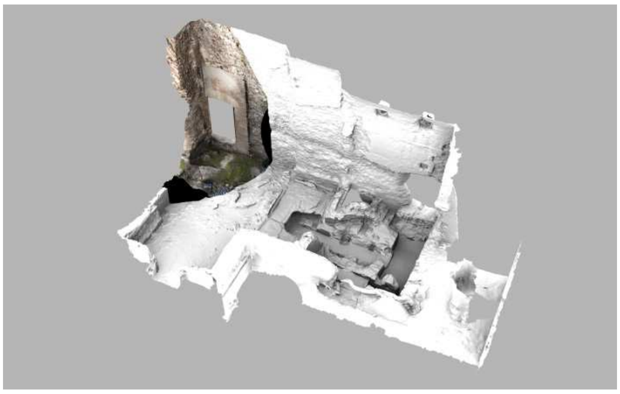
The peculiarity of this case is that the texturing will be done with the pictures taken with a fisheye lens and consequently, with a considerable spherical deformation.
The main problem is that no camera-matching software accepts images with a lens distortion, in such a way to realign the room 3d scene would be wrong and the result would be gravely lacking precision.

Fig. 17 – a fisheye picture before and after the lens correction

Consequently, it is necessary to correct this deformation with special software which are loaded in the database of the principal lenses and then it's possible to correct the deformation of the photo.
This operation must to be done on all pictures used in the texturing.
The next step is the calibration of the room in three dimensional space: for every picture this procedure is performed to set the characteristics of the camera and its position in space.
It's necessary to produce a matching to align the 3d model at the camera. This operation is accomplished with a series of geometries homologous detectable on the mesh and the image.
Then with a baking operation it's possible to generate a portion of the color texture on the UV map; so with a series of calibration and baking operations we have textures that covered the entire model.
Merging and color balance operations are needed to create a valid texture color.
This step is very important: the balance operation is very difficult because the shots of the digital camera are different characteristics of illumination and it's necessary to produce a texture with a lighting.

In some cases the photos have hard shadows, and the way to reduce this trouble is a post production using RAW pictures.





Figs. 18-19 – The texturing of a 3d model

Exporting in Unity

Unity is a software that allows to export the 3D models optimized on the web. It’s frequently used for the videogames because it allows to generate virtual environments with characteristics similar to reality.
In fact in the Unity interface it’s possible to set every ambient features, like sun direction, virtual sky dome, shadows, artificial lights, clouds and fogs.
This software allows to produce some “sensible points” with pop ups that describe the characteristic and the elements of this area.
For example this thing is usable to describe and analyze parts to the cultural heritage, maybe with interactive link and pictures.
It’s possible, with a download of a simple plugin, to see the model with any browser (for example Internet Explorer, Google Chrome, Firefox and so on) or with Android or Apple phones. With this technology is possible to navigate the 3D model like “walking through”.
After import the mesh and the various textures generated on Unity, indicating the points of collision and the camera position, indicate the type of lighting and possibly the type of sky to use, and you can export the model directly or browser on mobile phones.

Fig. 20 – The textured 3d model

Conclusions

The reading and the immediate navigation of a cultural heritage through interactive tools, such as the computer connected to the Internet or mobile phone, allowing several developments of using this model. This can be especially benefit tourists interested in inaccessible cultural heritage, which can virtually visit the site and with the help of pop up can learn more about different areas and how to use them.
It can be useful for teaching, going to have an interactive object can be analyzed and used.
It’s useful for archiving purposes of information and data: in this case, in fact, the boiler room, after the excavation, was recovered again to preserve the artifacts analyzed.
The problem is to produce a 3D model with more information and details, but at the same time it must be east to use with various electronic equipments. This is one way to generate this type of model, using a process similar to videogames scene, in fact the computers and the smartphones are configured for playing and navigate in virtual games.
It’s important to consider that the textured 3D model is usable to produce 2D drawings, like plans and sections and is a measurable model. So it’s possible to use like source of every dimensional analysis and representation.

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In the research promoted by Hadrianic Accademy of Architecture and Archaeology, since 2007 three excavation campaigns are made in the Small Baths, coordinated by Alessandro Blanco, Barbara Marzuoli, Francesca Mollo (co-authors of the plan in the figs. 1 and 7).
All the operations and researches in the Hadrian’s Villa are done in full agreement with the responsible for the Hadrian’s Villa area, dott. Benedetta Adembri from the “Soprintendenza Archeologica del Lazio”.
2007 and 2009 survey campaign was done in collaboration with Area3D s.r.l.. 2008 survey campaign was done in collaboration with Microgeo s.r.l.

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