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UNDERSTANDING ETRUSCAN ART AND ARCHITECTURE THROUGH 3D MODELING: THE CASE OF VOLTERRA

1. Introduction

For many years, archaeology has been confronted with the so-called hard sciences and technological innovations, including those relating to the 3D survey, modeling and representation. Over time, the approach of the archaeologists about these innovations has been swinging, going from an over-enthusiasm, which often resulted in the inappropriate use of available means, to a complete rejection.

Currently, since the archaeologist is more aware of the potential of these 3D modeling and visualization tools and, in some cases, like those presented in this paper, not only "customer" but also main actor in the acquisition and processing of data, the relationship has been settled and balanced, meaning that the technology is used in a critical way and bent to the needs and purposes of the scholar.

The team of Etruscology led by Professor Marisa Bonamici and the Laboratory of Drawing and Restoration (LADIRE) of the University of Pisa have followed the same path, joining in an ever more constant and systematic way the potential of the new technologies to the more traditional tools of study and analysis.

In this way it has gone from using physical replicas (scale models), to creating simple static rendering and videos (sector that goes under the name of Virtual Archaeology), up to interacting with 3D objects within immersive virtual environments (trend known as Cyber-Archaeology).

E.T.

2. Case studies

The case studies relate to projects, some of them still in progress, dedicated to sites, monuments and artifacts of the Etruscan town of Volterra, for many years under study by our working group.

The most complex and articulated site is undoubtedly the acropolis, that hosts the main Sanctuary of the Etruscan city.

The area was investigated several times since the 1920s, but only since 1987 has been object of systematic excavations that have enabled the reconstruction of a long sequence of building phases with temples and sacred courtyards following one another without interruption from the 7th century BC to the early Roman Empire (Bonamici 2003; Bonamici, Rosselli, Taccola 2017, 51-61).

Within a *temenos*, whose first installation dates back to the middle Orientalizing period, a small sacred building decorated with Campanian-style architectural terracottas was erected in the Archaic period and later, in the late Archaic period, a large temple was built, probably dedicated to the couple of gods founder of the Sanctuary and equipped with a fittile roof decorated by South-Etruscan craftsmen.

After more than two centuries without major architectural changes, the entire Sanctuary was completely renovated in the late 3rd century BC. First of all, the sacred area was enlarged with the construction of a new *temenos*, which included a large Tuscanic temple (Temple B), erected over the former one belonging to the Late Archaic period and overlooking a series of outdoor courtyards designed to worship by devotees, whose many different traces on the ground (hearths, votive pits, water supplies) still remain.

After about half a century, the Sanctuary received a further building renovation, which remained in use until the end of the sacred area frequentation. The Tuscanic temple was flanked by a smaller building of Italic tradition (Temple A) characterized by a single cell and oriented in the opposite way.

At the same time, on the southern side of the Sanctuary a temple of small size was also built, dedicated to Demeter, closing the sequence of outdoor courtyards devoted to the worship.

Over the past two years, the University of Pisa has extended its investigations to the necropoleis of the city. In particular, two long-known but not yet adequately studied and documented Etruscan tombs were excavated and surveyed.

The first one is the Hypogeum of Torricchi, located in the Etruscan necropolis that occupies the Ulimeto hill E of Volterra. This monument was already discovered in the last decades of the 18th century and again investigated in 2015.

It is a tomb entirely carved into the limestone rock, consisting of a large central rectangular *atrium* with benches along the walls, accessible through a little steep *dromos* provided with steps and covered by a vault, that was constructed togheter with a modern building erected above the ancient hypogeum. On the back wall of the central room there are three small rectangular chambers, each with benches along the walls.

This kind of complex plan tomb finds numerous comparisons at Volterra and in the surrounding territory with burials that can be dated between the 5th and 4th century BC.

The archaeological investigation has allowed to discover into a layer of earth to leveling the base rock a large number of small sherds belonging to the original funerary sets deposed in the hypogeum, dating between the third quarter of 4th century BC and the half of 2nd century BC (Rosselli 2016). The sherds thus testify that the tomb hosted several generations of the Etruscan *gens* who built it.

The excavation begun in 2016 in the locality Colombaie, still in progress, aimed at the investigation of a chamber tomb with false dome situated

in the middle of an artificial terrace on the south-western side of Volterra, with appropriate methods of excavation and survey.

The tomb, discovered already violated in the 1920s and once again investigated in 1959 by Enrico Fiumi, has never been adequately documented, so that its location was almost lost. It consists of a square hypogeic chamber, partly excavated in a natural gray clay deposit and partly constructed with rows of roughly hewn stones blocks.

The roof of the tomb was built with rows of jutting rectangular slabs, set over the cell walls to form a false dome, preserved only partially. The chamber can be accessed through a short and very steep *dromos* dug in the clay.

Widening the excavation area, a pile of small and medium-sized stones placed all around the tomb has been identified, which is perhaps to be interpreted as the remains of a large *tumulus* composed of earth and stones, in order to protect the burial room and its entrance.

This structure is one of the oldest examples of chamber tomb found in Volterra. It is an evolved form of large cash burials made up by square slabs of late-Villanovan period in Northern Etruria, and can be dated in the last decades of the Orientalizing period.

In addition to field work our team deals with the study of the archaeological collections in the Museum Guarnacci, one of the oldest Italian public museums.

Established in 1731 with a collection of cinerary urns found in the necropoleis of the Portone, the museum grew significantly in 1761, when the prelate Mario Guarnacci donated his collections of Volaterran archaeological finds.

Subsequently, the museum, known primarily for its large collection of urns, was enriched in the second half of the 20th century of many materials from the excavations carried out in the city by the then director Enrico Fiumi.

The museum, currently under redevelopment according to modern exhibition standards, illustrates the history of the settlement of Volterra, from the process of formation during the Final Bronze Age to its entrance into the Roman sphere, and includes archaeological finds mostly from the necropoleis surrounding the city, as well as a few artifacts from the urban area.

L.R.

3. 3D modeling techniques and their applications

The procedures used for the case studies range from computer graphics to 3D photogrammetric survey Structure for Motion (SfM). Initially, the virtual simulation of the Sanctuary of the acropolis in the late Archaic and Hellenistic period was built.

Leaving aside the description of the modeling techniques, it is worth dwelling on the planning stage and some solutions designed for the realization

of the work. In this regard it is necessary to point out that, unlike other case studies related to Etruscan sites, techniques of procedural modeling or BIM (or ArchaeoBIM) have not been used (Gaucci, Garagnani, Manferdini 2015; Garagnani, Gaucci, Gruška 2016).

The preliminary phase of the operations provided for the integration of data derived from the historical source, represented by the literary work of Vitruvius, who in Book IV of the *De architectura* describes the planimetric features of the Tuscan temple and the relationships of proportions that regulate its edification, and data taken directly from the archaeological fieldwork and the surveying activity.

This second aspect concerns the wall structures emerged during the excavations, the cultic installations and the artifacts unearthed within archaeological deposits: elements of the architectural apparatus (roof tiles, architectural terracotta decoration, plasters, bases and capitals) and objects related to the practiced cults (mostly pottery).

By crossing the archaeological data available with the literary source (as for the Tuscanic Temple) and with other examples from Southern Etruria (as for the Temple A, of Italic tradition) it was possible to draw a first draft reconstruction of the two buildings. Initially, these sketches were used for the creation of a 1:33 scale model by the Studio Pentagono for the exhibition *Etruscans from Volterra. Masterpieces from great European museums* (2007) and subsequently, for the virtual simulation of the Tuscanic Temple of the late Archaic period and the entire Sanctuary in the Hellenistic period.

Early simulations (2011) were created with AutoCAD, with positive results but not fully satisfactory about the management of textures and scene illumination.

In the years 2014-2015, thanks to more advanced software (3ds Max) it was possible to reconstruct the ancient landscape, creating a Digital Terrain Model (DTM) from cartographic basis, integrating new contour lines in correspondence with a modern-age landslide that engulfed much of the temple B, and other contour lines, by interpolating heights and gradients reached with the excavations.

In addition, the possibility to manage and edit more complex textures, to set an illumination that realistically simulates the natural one and to set the scene by placing the surrounding landscape, the sky and the vegetation, has contributed to the latest version of the virtual simulation as it can be seen in Fig. 1.

As for the fittile architectural decoration, peculiarity of Etruscan temples, a distinction is needed between the late Archaic temple and the Hellenistic temples. In the one hand, the amount and state of conservation of archaeological findings have allowed for a reliable reconstruction of the architectural decorative apparatus, while in the second one it was decided not to place any

Fig. 1 – Virtual simulation of the Sanctuary of the acropolis during the Hellenistic period.

element, since most of the fragments, unearthed during previous excavations, are not directly available for an accurate reconstructive hypothesis.

Turning to 3D photogrammetric techniques, two projects have been started that actively involve the University of Pisa and the Scuola Normale Superiore.

The first one concerns the 3D acquisition of the most representative hypogea of the necropolis of Volterra for their fruition within immersive and interactive virtual environments; the second one the 3D capture of a wide selection of objects preserved at the Museum Guarnacci, for which an interactive virtual exhibition (remotely or on platforms directly available in the museum) is about to be implemented.

At present, the tombs described in chapter 2 were acquired in 3D. As for the Museum Guarnacci, five 3D models, both from small and large artifacts, have been realized so far. The software used are PhotoScan Professional and MeshLab.

Even in these cases it is unnecessary to dwell on the methodology of acquisition of 3D data, but rather to describe some issues faced during the work. The main difficulties depended on the environmental conditions of the objects to be acquired. More specifically, issues related to artificial and natural illumination to weather conditions, to the position, visibility and accessibility of the object, to the possibility of moving the object, to the freedom of movement around it.

In many cases, during the processing of the 3D model it has been necessary to mask, i.e. virtually remove modern artifacts (Hypogeum of Torricchi and Tomb of the Colombaie) and background (for mobile objects of the Museum Guarnacci, for which it was more effective, in order to cover the entire geometry, to rotate the object holding the camera steady on a tripod, instead of rotating around the object).

Furthermore, with regard to the hypogea, the 3D photogrammetric acquisition was not limited exclusively to the structure of the monument but also to

the archaeological deposits identified and removed during the excavations, as well as to some objects found, all of them perfectly aligned as they share the same reference system, measured with total station and georeferenced with a differential Global Navigation Satellite System (GNSS) device.

4. Aims, results and outlook

The main goal of our team is to use and make the 3D models usable. In this regard, it is now common that the excavation documentation drawn up in our archaeological surveys (plans, cross sections, contour lines, Digital Elevation Model) is obtained by georeferenced 3D photogrammetric survey: this solution provides a higher level of accuracy, in addition to employ less time in the data acquisition phase in the field than traditional survey techniques (Fig. 2).

Moreover, the 3D model is a versatile object, i.e. suitable for use in multiple ways, besides the purely scientific, which brings us to the second aspect: making the 3D models available for external users. Regarding this issue, how has the relationship between the user and 3D object evolved in these years? By what means can he interact and which minimum skills are required? How does he react to the use of more advanced tools and the projection of his own person within immersive virtual environments?

The literature on this topic is already very broad, ranging from engineering to neurosciences (among the many: Witmer, Singer 1998; Pescarin *et al.* 2013; Gallese 2014), but here it is more appropriate to describe this interrelationship by relying on our direct experience and the various solutions devised for our needs and projects.

At the moment, two collections are available within the LADIRE channel on the platform Sketchfab, the first relating to a small selection of exhibits in the Museum Guarnacci, with which the user can easily interact and from which – in some cases – obtain information (Fig. 3), while the second one dedicated to the necropoleis in Volterra, at the time only to the Hypogeum of Torricchi, which can be visited both from desktop or in VR mode by using basic cardboard viewers (Fig. 4).

The project in progress, in collaboration with the laboratory DreamsLab of the Scuola Normale Superiore, will provide for the 3D survey of a significant number of underground tombs of the city of Volterra, a more detailed drafting of metadata and the development of an application that will allow to interact in a more complex and natural way within immersive virtual environments and directly on site (Carrozzino, Bergamasco 2010).

More in detail, thanks to more advanced headsets and by performing natural gestures, wearing controllers with the relative motion tracking systems, the user will be able to select the tomb required from a map, to move freely within it, to derive data such as measurements, distances, coordinates, to reproduce

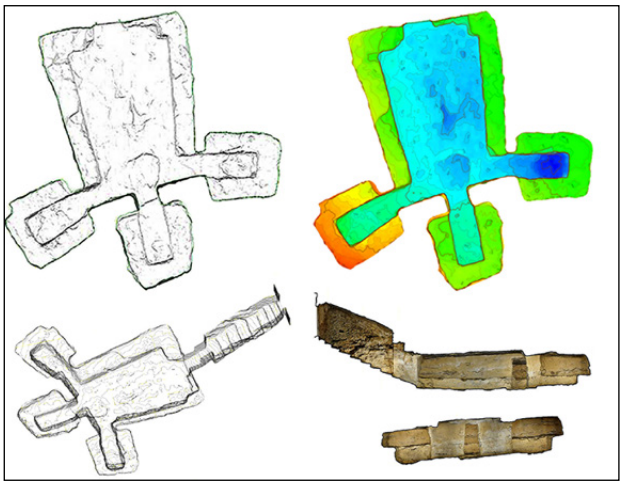

Fig. 2 – Hypogeum of Torricchi, from top left clockwise: general plan, DEM, cross sections and contour lines.

Fig. 3 – 3D model of the *Kourotrophos* Maffei (Museum Guarnacci) with annotations, as seen in Sketchfab.

Fig. 4 – Hypogeum of Torricchi in VR mode.

the sequence of excavation by removing or repositioning stratigraphic units identified during the archaeological excavation, to replace, wherever possible, the objects found in it, and to enable more or less complex annotations.

For now, a simplified beta version, available on Android platform, was presented during the FAI Heritage Days on March 25th 2017. With a simple cardboard viewer, the user can visit the Hypogeum of Torricchi and turn on or off with a visual interaction the most significant stratigraphic units and a special finding (a fragment of a human jaw).

This application is very simple and requires no special training or skills: the user simply wear the device, turn the head and body and watch for a few seconds where he wants to go or what he wants to turn on or off.

This first experiment obtained very large interest and enthusiasm among visitors, almost all of whom had not yet had the opportunity to approach this kind of technology.

Future outlook of our working group is, on the one hand, the increase in the number of models of the artifacts collected in the Museum Guarnacci and the development of a dedicated application, separated from Sketchfab, on the other hand, displaying the virtual simulation of the Sanctuary of the acropolis within a CAVE-like (Cave Automatic Virtual Environment) system with a modality of interaction similar to that one already developed in a project that has seen the participation of LADIRE laboratory, concerning the ancient agora of Segesta in Sicily (Olivito, Taccola, Albertini 2015; Albertini *et al.* 2017).

5. Conclusions

Virtual simulations provide scholars with fundamental assistance for validating conjectures, elaborated so far without the support of advanced technological tools.

The ability to visualize and interact within immersive virtual environments allows to appreciate in a more complete way volumes, distances, reciprocal visibility, natural and artificial lighting effects, developing a sensation of embodiment (Forte 2016) that binds strictly user and virtual environment and that involves other senses in addition to sight, so far impossible by using traditional tools.

Moreover, these simulations provide an essential support for scientific communications allowing an immediate understanding compared to showing only archaeological ruins, sometimes very little decipherable even to experienced eyes, especially in cases – such as the acropolis of Volterra – where several building phases followed one another over the centuries.

Finally, it has not to be underestimated the impact at didactic, educational and disseminating level that flows and ensures the public of non-experts a better and more effective fruition, especially when projected within immersive virtual environments. Not to mention the benefits of such technological solutions to those suffering from motor disabilities, which do not allow physical access to the monuments, in most cases difficult to reach and often closed to visitors.

The very positive response to this new type of visualization and interaction represents a valuable incentive for prosecuting and developing this research field.

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WEB RESOURCES

Laboratory LADIRE Youtube channel:

https://www.youtube.com/watch?v=SJoF6ZjUpSM&t=37s (Hypogeum of Torricchi).

https://www.youtube.com/watch?v=K4QMKKuKlME (Kourotrophos Maffei, Museum Guarnacci).

Laboratory LADIRE Sketchfab collections:

https://sketchfab.com/leletaccola/collections/necropoli-di-volterra (Hypogeum of Torricchi).

https://sketchfab.com/leletaccola/collections/museo-etrusco-guarnacci-di-volterra (Museum Guarnacci).

ABSTRACT

Nowadays, archaeology and modern 3D modelling and representation technologies form an unbreakable bond, considered essential and indispensable by many experts and scholars. Although with different goals and purposes, new hardware and software available and specially designed web platforms allow the archaeologist adequately trained to create, visualize, analyze, and share 3D data derived from computer graphics or from image- and range-based acquisition procedures. Currently, a very important topic is the relationship between user and 3D model: from the simple passive fruition, we are moving increasingly towards a real interaction within immersive virtual environments. In this sense, the contribution of the archaeologist is critical to determine what to display and what to interact with, according to the end user and his skills and knowledge. In fact, the following case studies related to sites, monuments and artefacts of the Etruscan town of Volterra represent the evolution of this interaction/relationship, helping to make the fruition of archaeological evidence, that at present is still difficult to access and understanding, easier and more interesting.