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Virtual Reconstruction of an Etruscan Tomb

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Abstract: This paper describes the main phases of an ongoing project regarding the 3D virtual reconstruction of an Etruscan hypogeum together with the funerary equipment it contained. The tomb is dating back to late Hellenistic period. It was discovered in 1880 in Sigliano, between lake Trasimeno and lake of Chiusi in Central Italy. This sepulcher is a paradigmatic testimony to enlighten the processes of settlement and land use during ancient times in a district (Valdichiana) with a strong vocation for agriculture and forestry. Furthermore, this reconstruction allows to relocate in their original context some finds now kept at the Archaeological Museum of Perugia, together with some other lost goods, documented by detailed sketches and drawings only. Hence, 3D modeling and 3D scanning have been combined to present the plausible appearance of the tomb when it was discovered. Some of the most interesting objects have been 3D scanned to provide accurate data. Particular care has been devoted to the 3D model of a probably gilded bronze helmet, a Southern Italy production (probably from Taranto) dated 4th century BC. A portion of plausible landscape has been modeled taking into account the geomorphology obtained through Google Earth, to locate the grave, and to insert it in a possible context. Moreover, following the indications found in the original sketches, the interior of the tomb and some of the smaller objects have been modeled. All of the generated data have been used to produce a video which will be shown at the Archaeological Museum of Perugia.

Keywords: 3D scanning, 3D reconstruction, virtual reality

Introduction

Information and Communication Technologies (ICT) tools can largely enable a better knowledge and fruition of Cultural Heritage. The archaeological field especially benefits from many different technological contributions, taking advantage of the excellent opportunities that virtual integration and rendering are able to offer to various audiences. Virtual reconstruction, for example, allows scientist and tourists to visualize how archeological finds were placed inside lost or inaccessible site, as well as to obtain a virtual visualization of objects that have not reached our days. The reconstruction can be obtained using the typical means of documentation of classic archeology, which are essentially composed by text, sketches and images. Virtual reconstructions make use of 3D models, which are a numerical description of an object that can be used to render images of the object from arbitrary viewpoints and under arbitrary lighting conditions. Three-dimensional digital models can be created with modeling tools or using 3D scanning devices.

We tested these technologies on an Etruscan tomb dated 2nd century BC, which does not exist anymore. The tomb was accidentally discovered in the XIX century, but an accurate description of the structure and the objects it contained was made by the Inspector to the Ruins and Ancient Monuments in Umbria Mariano

Guardabassi (1823-1880) (GUARDABASSI, 1880), and Luigi Carattoli (1850-1894) (Carattoli, n.d.), both members of the Artistic Provincial Commission. In addition, the German archaeologist Wolfgang Helbig wrote an account about the discovery (HELBIG, 1880). Figure 1 shows a page of one of the accounts used for the reconstruction.

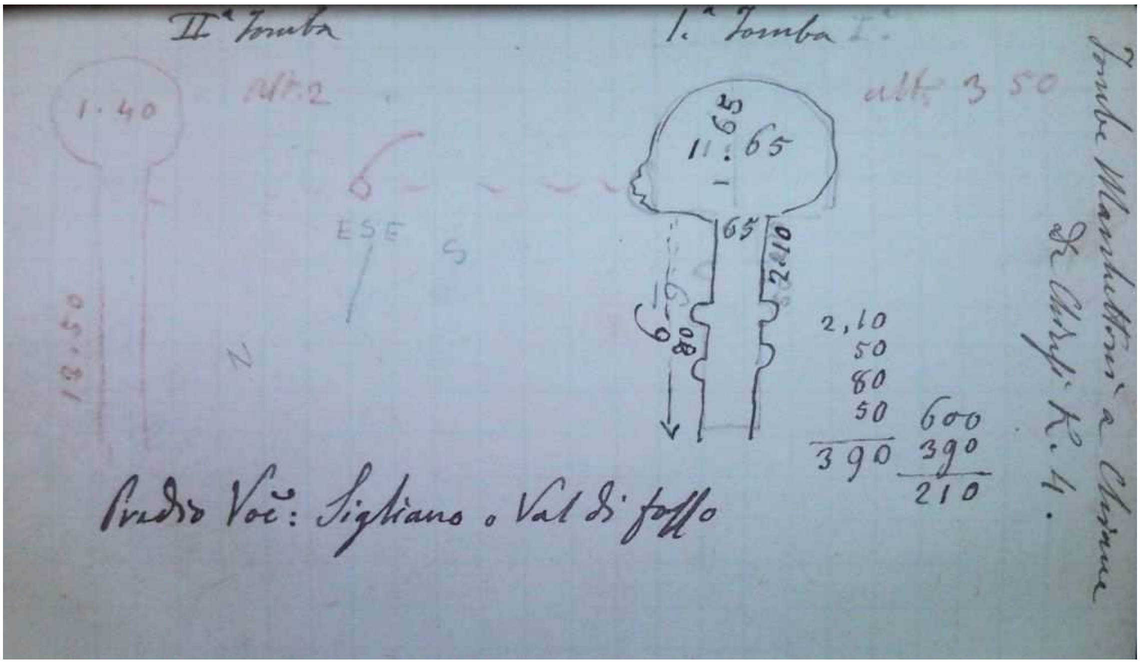

Fig. 1 – A page of one of the accounts used for reconstruction, showing a sketch of the structure of the tomb. (Photo courtesy of Biblioteca Comunale Augusta, Perugia).

Thanks to the written and graphic documents they left, we could extract information about the tomb location, its plan development and all the objects it contained. At the moment, some of them are exposed in the National Archaeological Museum of Perugia, but some others are definitely missing. The preserved nucleus includes three cinerary urns in travertine stone with inscriptions and a beautiful, probably gilded bronze helmet. Epigraphic evidences allow us to identify the owners of this tomb in a branch of Tetina family. Hence, we decided to use 3D acquisition for the main objects which are still available, and to combine the acquired models with 3D reconstruction based on modeling, following the indications and the sketches of the original accounts.

Using 3D scanners and processing software, we generated accurate 3D models of all artifacts found in the tomb (four urns and a bronze helmet). In addition, through archive information and comparisons with Etruscan artifacts of analogous graves in the same period and social status, it was possible to model a 3D reconstruction of the tomb and put the acquired 3D models of the objects, as well as virtual models of all lost artworks, inside the virtual environment.

Notes on the archaeological context

The Etruscan hypogeum was discovered in 1880 in Sigliano - Val di Fosso near Chiusi, in Tuscany, along with another similar tomb, as a part of a small necropolis. According to the excavation report, it was dug directly into bedrock, and geological studies confirm that it was created excavating a sequence of layers composed of clay, pebbles and fine sand deposited in the Pliocene. Planimetry consisted of a single burial chamber preceded by a long corridor (*dromos*) with four niches - two on each side - sealed by tiles in the wall. The inscriptions on the urns allow us to state that the tomb belonged to members of *gens* Tetina, one of the eminent *nomina* in the Chiusine society of 2nd century BC. Two free men and a woman were buried in travertine urns, a fourth terracotta urn contained the ashes of a freedman. Some aspects of this funerary complex are very interesting. First, the presence of an excellently crafted gilded bronze helmet must be highlighted; it is rightly considered by scientific community a masterpiece of ancient metalworking. The helmet was found inside the *paterfamilias* chamber and it is dated 4th century BC; it is probably part of the spoils of war conquered by an ancestor, and carefully guarded by his family as a sign of glorious past and of military honors. A second attractive topic is related to the burial of the *lautni* Zerapiu, a freed slave of Eastern Mediterranean origin, whose remains were deposited inside the first left niche along the *dromos*. The published excavation reports say that the urn was accompanied by several fragments of bronze objects, including three *oinochoe* handles, two large “bracelets” with ornitomorphic decorations, a mouth of vase, nails and pieces of coating plates. Some peculiar iron fragments that we can attribute, probably, to specific tools for wood turning, like reamers and gouges, were discovered as well. It is therefore to speculate that the freedman was a skilled craftsman in metal-woodworking. This hypothesis is intriguing whereas we consider that the landscape is until now characterized by extensive woodlands, and the area is mentioned by historical sources as a supply zone of sturdy timber for the construction of the Roman fleet of Scipio at the end of 3nd century BC (cfr. T. LIVIUS, *History of Rome* XXVIII, 45).

Uses and combination of 3D data in cultural heritage

Three-dimensional data are increasingly integrated in several contexts in Cultural Heritage, ranging from the presentation to the public to the support of the work of experts. An overview of the projects involving 3D data goes well beyond the scope of this paper, since from the seminal 3D Scanning campaigns (LEVOY et al., 2000), a number of 3D scanning projects or major 3D Reconstructions (FRISCHER et al., 2008) has been proposed to the community. The advantages and challenges of the combination of different 3D technologies has been already discussed in several works (BERALDIN et al., 2005), although some open issues are still discussed by the community. Some of these issues regard the need for high accuracy, the distinction between acquired and modeled data, the need for a standard data format for three-dimensional data. An interesting example of an integrated work is the *Parthenon project* (CALLIERI et al., 2006), where 3D Scanning, 3D modeling and illumination environment acquisition were combined to provide an extremely realistic video where the Parthenon and its sculptural decorations, separated since the early 1800s, were reunited. Recently, the advent of dense stereo reconstruction techniques (GOESELE et al., 2007, FURUKAWA & PONCE, 2010) gave the possibility to obtain dense point clouds of objects of varying size, starting from a set of uncalibrated images. These methods can produce a 3D representation of extremely complex environments, using for example images taken from community photo collections (AGARWAL et al., 2009), which can represent a perfect starting point for further modeling or integration with 3D scanned data.

Regarding the project presented in this paper, a similar action in the context of Etruscan Heritage is currently brought on in the context of the *Etruscanning project* (ETRUSCANNING, 2011), where 3D Scanning, 3D Modeling and VR techniques will be used to support three exhibitions on the Etruscan culture.

3D acquisition and data processing

Many different technologies have been developed for 3D acquisition (laser triangulation, structured light, conoscopic holography, time of light, etc.). The technology to use depends on the characteristics of the objects that need to be acquired. In Cultural Heritage field, high precision is often required: this restricts the possible choices of the technique to adopt for digital model production. In this project, due to the size of the object and of the detailed geometry, it was decided to use a laser triangulation scanner (Minolta Vivid 910).

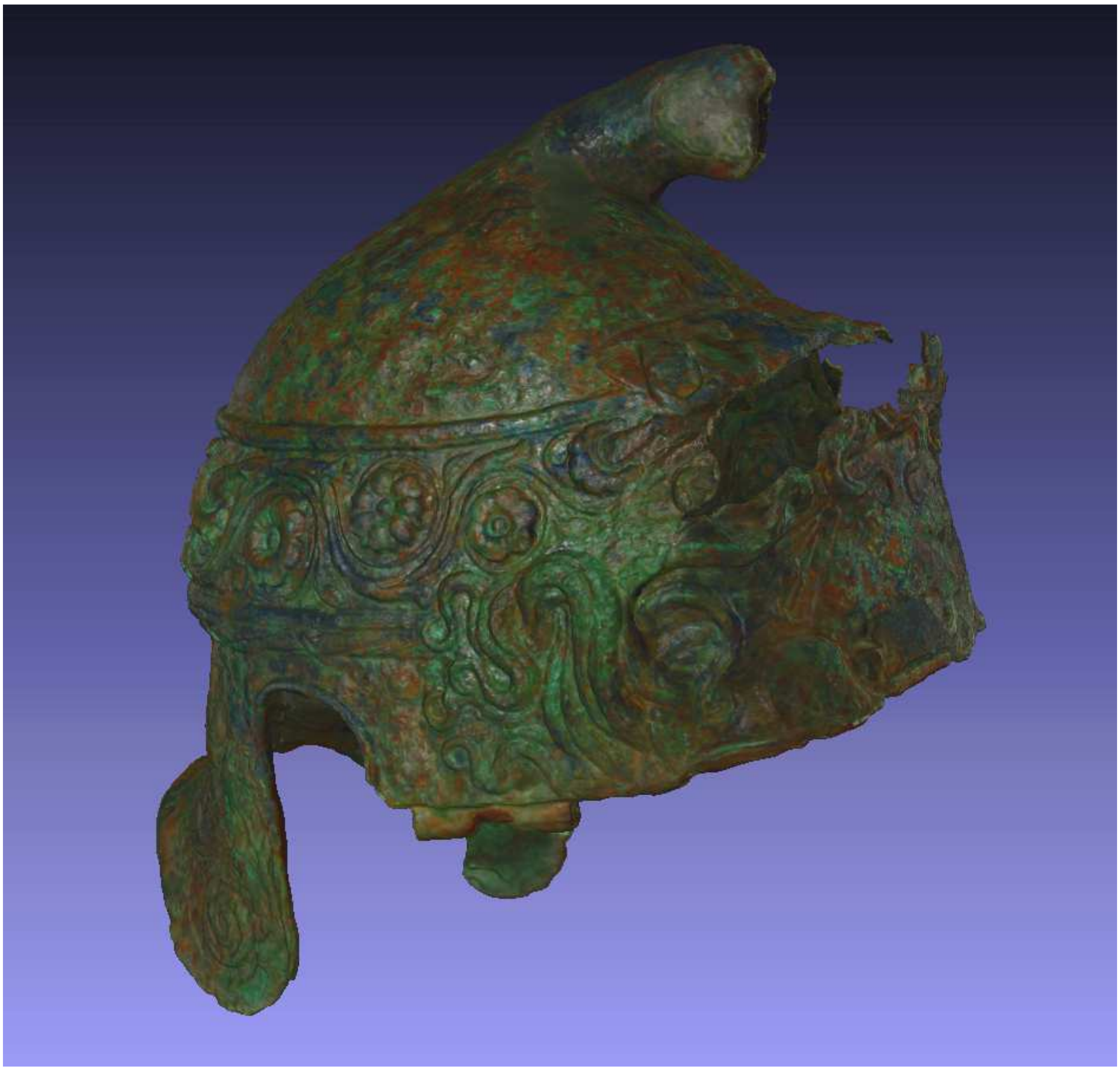

Fig. 2 – A snapshot of the helmet 3D model obtained via 3D Scanning.

In general, in order to generate a complete 3D model, the object has to be scanned from different points of view in order to cover the whole object's surface. In this phase particular attention has been given to guarantee a reasonable overlapping between neighboring range maps. During the campaign of scanning at the Archaeological Museum of Perugia the bronze helmet (see Figure 2) and four urns (three in travertine and one of terracotta) were acquired by 3D laser scanning. The metallic artifact and the three stone cases come from the tomb of Sigliano; then, we chose to capture even the terracotta urn, which, although not being the one originally found in the tomb of the servant Zerapiu, as reports refer, is still perfectly plausible as a model. The type and the subject represented in the decorative front face correspond to a characteristic serial production of the area of Chiusi, which does not present significant variations in its apparatus (except for the name formulas).

Sampled data were processed to obtain complete 3D models (CALLIERI et al., 2003). Elaboration consists of an alignment step of the range maps, cleaning of the areas that do not belong to the object (for example the base on which the object was placed), integration of the range maps in a single unified model. In parallel, a detailed set of photographs was acquired for each object from different angles. The images were aligned to the 3D model (CORSINI et al., 2009), so that the color information could be projected on the geometry (CALLIERI et al., 2008).

Both the geometry and the color processing were fully performed using MeshLab (CIGNONI et al., 2008), an open source mesh processing tool. The final 3D models were then prepared in different versions: a high resolution one (see Figure 3), with color-per-vertex, as documentation of the actual state of the artifacts, and a lower resolution one (using texture mapping to depict the color) to be used during the rendering process.

Virtual reconstruction

Another goal of this project was the creation of a virtual model of the tomb based on bibliographical notes, archive information and archaeological assumptions, together with the modeling of the lost artifacts to be relocated - along with 3D scanning acquired objects - inside the original context. Effective software to reach these objectives is Blender, an open source 3D modeling tool, that is able to model the surface and appearance of a 3D model, as well as to import various 3D data formats and create and edit video sequences. Several aspects at different size have been modeled and used for the video generation.

The tomb

The description of hypogeum given by Guardabassi refers to a structure with a long open air corridor and a funerary chamber at the end, following a pattern known in various burial contexts close to it during the same period. For the tomb modeling, information contained in (GUARDABASSI, 1880) was used, enhanced by details about geographical position of the archeological finding, metric and topological data drawn in a sketch of an unpublished diary (GUARDABASSI, n.d.) (Figure 1). According to these sources, the tomb consisted of a corridor 0.65 m wide and 6 m long, with four locules (0.5 m high and 0.75 m wide). The first couple of locules were 2.10 m from the entrance and the second one is 0.80 m farther. At the end of the passage at the depth of 3.5 m there was the circular chamber (diameter 1.65 m), provided with a step. Beginning from a lowpoly model (1200 faces) various subdivision levels were applied (the final model has 1.3 million faces),

Fig. 3 – A snapshot of a high resolution 3D model of one of the urns.

and with the use of sculpting tools the appearance of the model was improved. In particular, the tomb was derived from a plane by extrusion, attempting to introduce some irregularity in the structure by using small translations and rotations. In order to obtain a realistic material to associate to the tomb mesh, the appearance of a ground section examined in a neighboring place was taken into account. Since the material was too complex to obtain using procedural textures, an image texture, similar to the original material, was used. A bump map was computed from the image texture and applied to the mesh in order to affect the normal to produce a deformation effect. Figure 4 shows an example of a rendering of the reconstructed tomb.

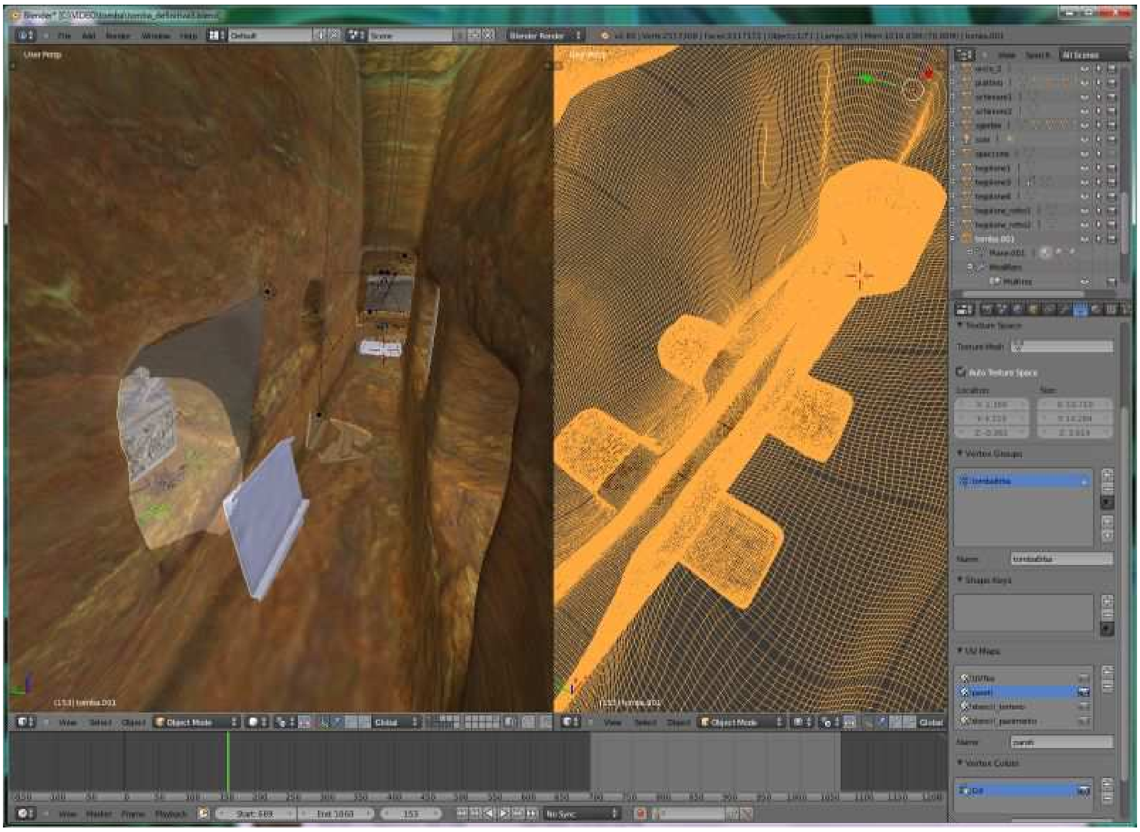

Fig. 4 – An example of rendering of the reconstructed structure of the tomb

Small artifacts

The information in the Guardabassi diary (GUARDABASSI, n.d.) and in the published papers of Guardabassi and Helbig (GUARDABASSI, 1880; HELBIG, 1880) did not provide detailed information about the bronze, iron and ceramic artifacts. Fortunately, some notes containing a series of drawings by Luigi Carattoli (CARATTOLI, n.d.) are preserved in the Archive of the Deutsches. Archaeologisches Institut in Rome. The drawings were made with great care and accompanied with precise measurements, thus useful to take as a precious reference for the virtual reconstruction of the objects. The objects with circular section (vessels, plates, etc.) were modeled by rotation starting from a profile. Ad hoc methodologies were adopted to model the objects with more complex geometry, which were often made in different parts and then assembled. The natural irregularities of the geometry were introduced by hand. Then, on the basis of the excavation report, the objects were virtually replaced in their original location. Figure 5 shows the sketches and the virtual reconstructions of a bronze “bracelet” and a bronze handle of vase.

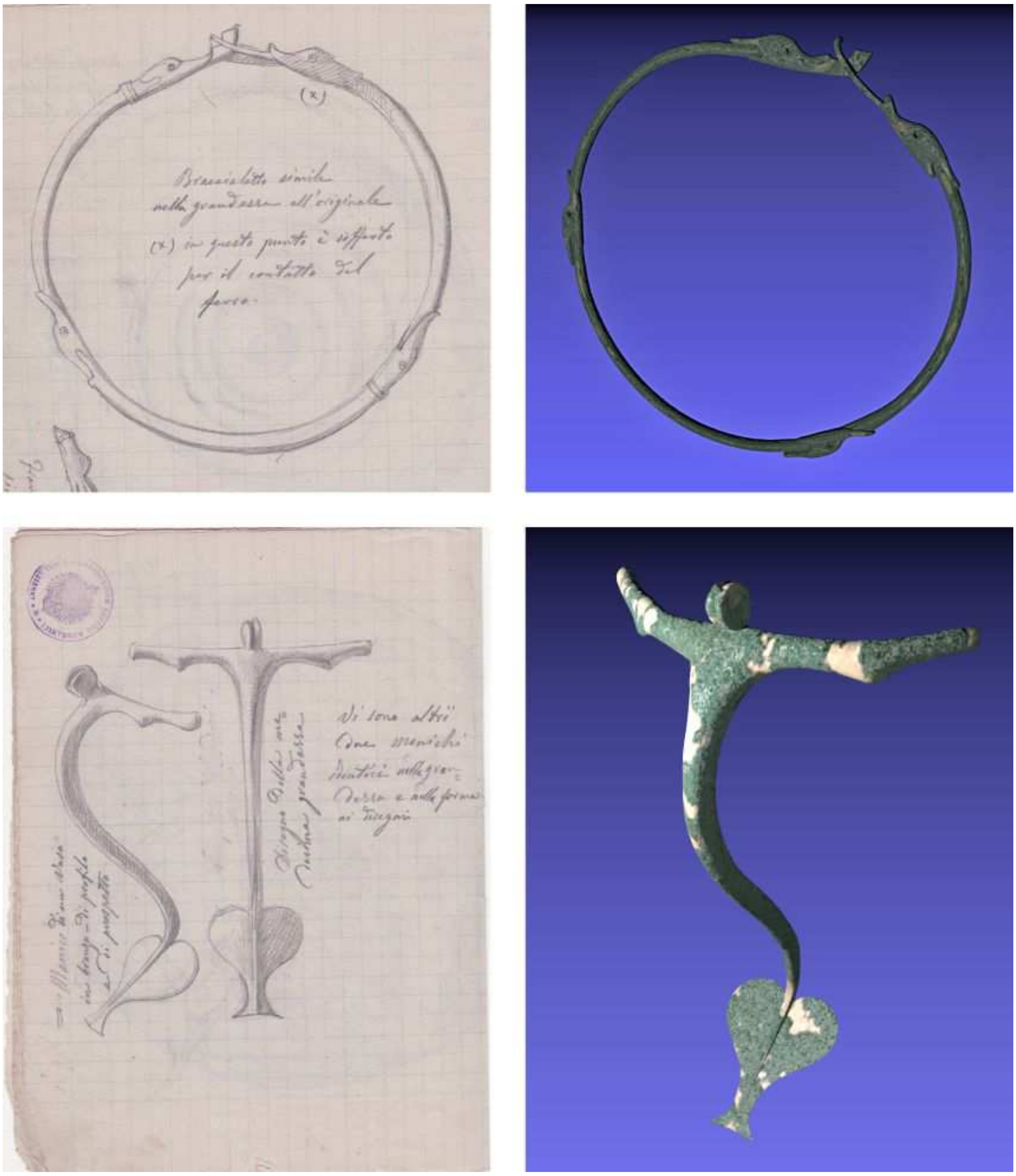

Fig. 5 – Top row: the original sketch and the 3D model of a bronze bracelet. Bottom row: the original sketch and the 3D model of a bronze handle of a vase. (Photo courtesy of Deutsche Archäologisches Institut, Rome).

Landscape

The project included in its goals the making of a documentary video showing the tomb with the artifacts and the findings obtained. To locate the grave and give the camera more freedom of movement, a portion of landscape (approximately 5000 sq. m.) surrounding the entrance of the tomb was modeled. The use of GIS methodologies for an accurate reconstruction of the landscape was not needed, since the zone underwent major modifications since the discovery of the tomb. Moreover, no useful indications were found in the original accounts of the discovery. Hence, a plausible landscape was modeled taking into account the geomorphology obtained through Google Earth.

Virtual restoration of the bronze helmet

The bronze helmet is a masterpiece of ancient metalworking (GUZZO, 1990). It is shaped like a Phrygian cap, with a smooth calotte and ornate decoration in a lower band that runs around the perimeter, from forehead to neck guard. It was originally covered with a gold leaf, which made it a particularly valuable object.

Unfortunately, the object was severely damaged by oxidation and deformed, probably by minor collapses of the main chamber. The actual state prevents from fully appreciating the object and its importance in the original arrangement of the tomb; for this reason, it was decided to carry out a "virtual" restoration, in order to present to the viewer the possible original aspect of this masterpiece. This process was carried out using different software tools: MeshLab, Blender and Zbrush. After creating the model representing the actual state (from the 3D scanned data) using MeshLab, the model was "straightened" in ZBrush to correct the global deformations caused by landslides in the tomb.

The missing parts were integrated by modeling simple fillers inside Blender, and then welded to the model geometry inside MeshLab. The final step, carried out again inside Zbrush, was aimed at removing the local geometry imperfections caused by the oxidation, to give better definition to the eroded repoussé and chiseled decorations, and sculpt the missing parts using as a template the symmetric areas of the helmet decoration (Figure 6). The restored model has been rendered using a material able to replicate the gilded bronze.

Fig. 6 – A snapshot of the helmet model before and after the virtual restoration: missing parts have been integrated, and the definition of the decorations has been improved.

Results

All the data which were generated during the acquisition and modeling phases were integrated and used to produce a comprehensive video which should help the tourist to gain a more accurate understanding of the context in which the museum objects were found, and their importance for the local history. This section shows some of the preliminary frames of the video, which is currently under production.

The structure of the video is divided in several segments:

The first section makes use of Google Earth to territorially localize the places of the eastern *ager clusinus* where several tombs similar to the one of Sigliano were found. Moreover, in this phase the video shows a plausible virtual reconstruction of a landscape (Figure 7) in which the 3D model of the grave has been placed.

The second section focuses on the internal structure of the hypogeum, along with the description of all burials situated by the side of the *dromos* and in the *cella* (see Figure 8). The different social class of the deceased is attested specially by the difference resulting from the cinerary types found: the remains of the freed slave were contained in a cheap earthenware urn, while three urns in travertine (more expensive) preserved remains of a free woman and two free men who belonged to *gens Tetina* of Chiusi.

The third section shows in detail the deposition inside the principal chamber, with funerary objects associated to the founder of the sepulcher Larth Tetina (Figure 9). Particular attention has been given to the bronze helmet found in front of the step that supported the cinerary urn (see section VI). In order to distinguish modelled artworks from acquired objects, the first ones have been rendered in the video with a grey color.

The concluding section highlights historical and arche- ological meanings of the monument in relation to the family history and territory.

Fig. 7 – Virtual reconstruction of the landscape.

Fig. 8– The dromos.

Fig. 9– The burial chamber.

Conclusion

In this paper, we presented a project where 3D Scanning and 3D modeling were combined to valorize some objects which are currently shown in the Archaeological Museum of Perugia. Scanned and modeled data are currently used to generate a presentation video, which should underline the importance of the tomb.

The sepulcher is a paradigmatic testimony in the historical background of the area, because it shows clearly not only the history of an Etruscan family, mutual ties and position inside the network of social links with the

urban site of Chiusi, but it also permits to focus on the dynamics of settlement and landuse during ancient times in a district of Valdichiana with a strong vocation for agriculture and forestry.
Knowledge and communication on this aspect of oldest stages in life of this area invites the present collectivity to reflect on current dynamics of change affecting the landscape, and allows the whole social group to regain memory of many *disjecta membra* of the past, missing in the underground or exhibited in museum display cases, virtually coming back to their primary context after a forced removal due to historical (or natural) events.
The virtual restitution is a valid instrument to help visitors or scholars to better understand a context that is still little known. It allows navigating within the grave, giving visitor the opportunity to "explore" the original context, actually seeing a patrimony otherwise difficult to remember because it is physically lost and dismembered. Thanks to synergy between specific skills in humanities and application of modern visual technologies, this path is an appealing way of talking about cultural heritage, to preserve and make it available to a large number of people, sensitizing them to care for their territorial responsibilities and their common goods. The resulting video of this work will be shown at the National Archaeological Museum of Perugia.

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