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ETRUSCAN ROCK-CUT TOMBS WITH DECORATED FAÇADES. A 3D APPROACH

1. Introduction

The rock-cut tombs are typical for the Etruscan funerary architecture in the inland of Southern Etruria (currently in the regions of Tuscany and Lazio, Italy). The occurrence of the rock-cut architecture is determined by the geomorphology of the area. Indeed, the main elements of the landscape are vast flat plateaux of volcanic tuff stone bedrocks intersected by deep canyon-like valleys with steep cliffs created by rivers (Perugi 2002). The volcanic tuff stone is light, porous, very soft and thus easy to cut and to be worked in various shapes. The Etruscans took advantage of these characteristics in the construction of various kinds of rock-cut architecture, such as roads, tunnels, cisterns and also as a building material. They excavated their tombs in the natural vertical tuff cliffs in proximity of settlements and concentrated them along roads. The construction of rock-cut tombs began around the second quarter of the 6th century BC and vanished around the beginning of the 2nd century BC due to the changes within the Etruscan society and culture caused by the Romanisation (Steingräber 1996).

The study of the stylistic evolution of the external decoration of the rock-cut tombs has led to several attempts to establish nomenclature and typology (Rosi 1925, 1927; Bianchi Bandinelli 1929; Oleson 1982; Maggiani 1994; Steingräber 1996). As a matter of fact, the analysis of the façades allows to understand the evolution of the decorative styles and can help to determine the chronology of the tombs, since many burial chambers are collapsed or robbed of the material finds needed to determine the chronology (Maggiani 1994, 125-127). Moreover, the façades are exposed to agents of weathering (i.e. water, lichens, roots of the vegetation). They enlarge the natural cracks in bedrock, cause the formation of new cracks and disrupt stone surface (see Canuti *et al.* 2004; Ciccioli *et al.* 2009). The comparison between the drawings of the first explorers from the 19th century or archaeological drawings made during the excavations conducted throughout the 20th century and the actual situation show the slowly diminishing of the details of the decorations (Dennis 1848; Canina 1851; Carter 1974; Colonna di Paolo, Colonna 1978).

2. The project

The project concerns the application of multi-image photogrammetry technique in documenting the decoration of the rock-cut tomb façades. The 3D models obtained by this technique could serve not only for the documentation and conservation purpose, but also significantly contribute to the archaeological analysis and thus to the chronological classification of these monuments. Moreover, it deals with further use of the acquired 3D models. The project focuses on the architecture of the tombs dated to the Hellenistic period (from the 4th century BC to the end of the 3rd – beginning of the 2nd century BC). In this time an important change in architecture of the tombs took place. This change was manifested mainly in the tomb façades, namely in the creation of new types and their variability, elaboration of the carved relief decoration and monumentalization that increased compared to previous periods. During this period, the imitation of the sacred architecture (various forms of *aedicula* and temples) and the decoration with figural and floral motives in relief widespread, mainly in the necropoleis of Sovana (ca. 30 tombs), Norchia (3 tombs) and San Giuliano (3-4 tombs) (Maggiani 2014, 298). Some tomb façades from Sovana and Norchia, among the most preserved, were chosen as case studies.

The use of multi-image photogrammetry technique has many advantages. By means of the obtained 3D models we can study these monuments in the virtual environment. Experimentation with modification of light conditions and visualisation of mesh reveal features on the tombs surface, that are hardly or not at all visible by the naked eye in the natural conditions. The use of point cloud or orthophoto leads to more accurate drawings, obtained in shorter time if compared to traditional manual measuring and drawing. Repeated high-accuracy scanning in time could help in monitoring of the changes of the surface caused by weathering. Moreover, close-range multi-image photogrammetry is particularly suitable because the scanning phase is performed without direct contact and so we can avoid further damage to the monuments and as well collect data from hardly accessible positions and places. This point is also the weakest one and the main disadvantage and limitation of the close-range multi-image photogrammetry – the need for a good view on the surveyed object. Finally, rendered 3D models can serve for the creation of the virtual anastylosis and virtual reconstruction of the tomb façades, for public exhibitions and be shared on internet with academic community and public.

3. 3D survey

The survey of the rock-cut façades was conducted through the close-range multi-image photogrammetry technique. This method is already well-established and known in archaeological documentation and because of this reason the general workflow is described briefly (Forte *et al.* 2012). The images were captured from nadiral and convergent positions overlapping approximately in 60% with a digital DSLR camera (Nikon D3300 body, 24 Mpix with an AF-S Nikkor 18-55 mm, f3, 5-5,6 VR lens) mounted on a monopod. On each object direct measurements of at least two recognisable points were taken manually. The off-site post-processing of the acquired images in open-source and low-cost software followed after this fieldwork phase. Processing was done in semi-authomatic way in four standard steps in Agisof Photoscan software: 1) performing the alignment of images; 2) building a dense point clouds; 3) building the mesh; 4) building the texture from the same images used in the point cloud reconstruction. Finally, the textured model was scaled using the measurements taken on site. The mesh of the façades with more complicated decoration and of greater size was built in the software MeshLab in order to use the Poisson Surface Reconstruction algorithm to create mesh with a specific level of geometric detail and to eliminate noise and holes in the mesh itself.

The point cloud and the mesh obtained can be used to produce orthophotos and subsequent archaeological drawings (for example in AutoCAD software). Meshes of more 3D models can be joined and positioned to create virtual anastylosis.

4. Virtual anastylosis

To demonstrate the further use of the obtained 3D models for the virtual anastylosis were selected two case studies: the so-called "Tombe doriche" from the necropolis of Acqualta in Norchia and the pediment of the "Tomba dei demoni alati" from the necropolis of Poggio Felceto in Sovana. Indeed, both façades have several fragments of the decoration preserved nearby in the site and in museums.

As first step, 3D models of all fragments of the pediments of both tomb façades were rendered. The models were scaled in Agisoft Photoscan according to two measured points on each of them. From 3D models of the better preserved parts have been taken orthogonal images. They served as a base for drawing the main outline of the decorative elements. Thanks to the symmetricity and repetition of the motifs in a pattern, the main outline of the better preserved parts can be projected on the place of the missing parts as mirror image. This creates the drawing of the hypothetical original outline of the whole pediment and helps us to place 3D models of the smaller fragments in the correct place. All 3D models of the fragments and façades were imported together in MeshLab and moved to the assumed right position by rotating and moving them along the axes (Fig. 1). For the purpose of recreating the original aspect of the façade, we do not have to scan the fragments in detail from all angles but to focus on the side which is part of the frontal surface of the façade. However, the side parts help to recognise the contact areas of the surfaces of the fragments and the façade and thus to place 3D model in the most exact position as possible. Finally, to the mesh can be further added a new mesh in the software Blender. Thanks to it we can close the space of the missing parts between the fragments and sculpt it in order to restitute the lost decoration, creating in this way a partial virtual reconstruction.

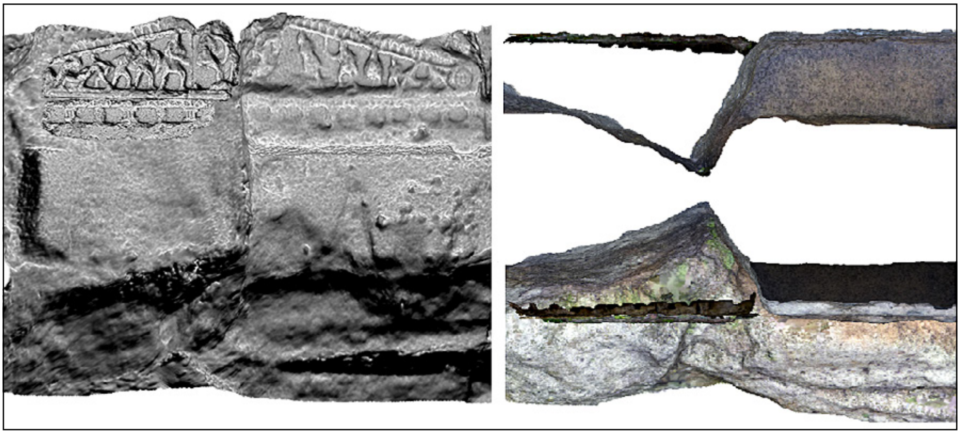

Fig. 1 – 3D model of the “Tombe doriche”, necropolis of Fosso dell’Acqua Alta in Norchia.

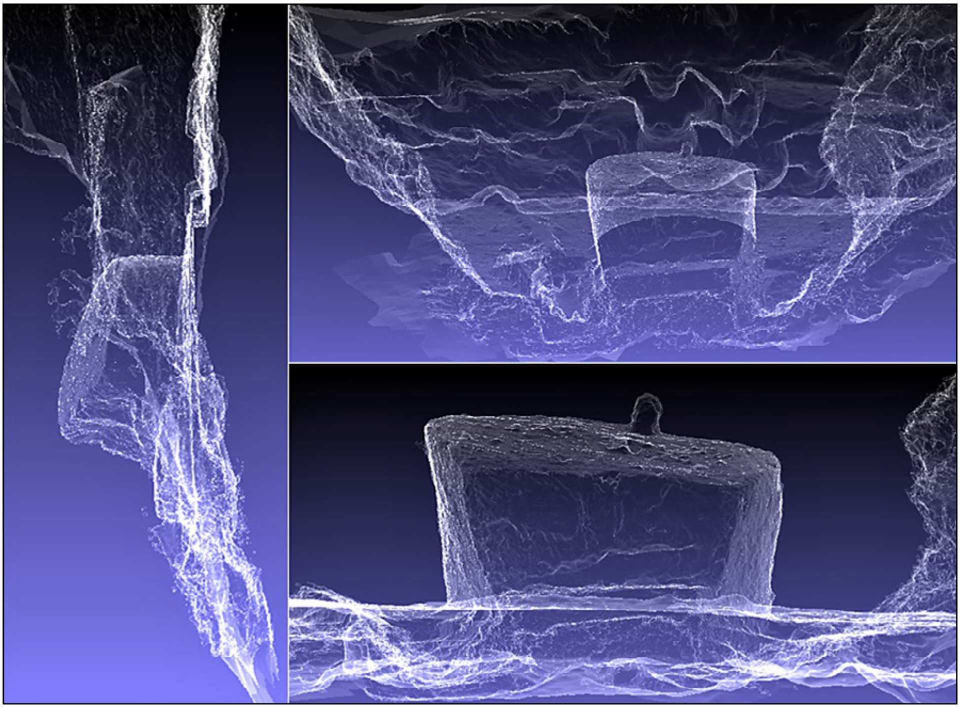

Fig. 2 – The analysis of the structure in MeshLab.

Fig. 3 – The comparison between unmodified 3D model of the "Tomba della Sirena" created in Agisoft Photoscan software (on the right) and 3D model of the virtual reconstruction after sculpting and retopology created in Blender software (on the left).

5. Virtual reconstruction

The virtual reconstruction of the tomb façade has been tested on the "Tomba della Sirena" (Carter 1974) and the pediment of the "Tomba dei demoni alati" (Barbieri 2010), both from Sovana. As first step, we studied the actual state of the façades and analysed their 3D models. By using different tools – various shaders such as Radiance Scaling and changing light conditions in MeshLab – the readability of the surface increased and helped to identify outlines and shapes that are hardly or not visible by the naked eye (Fig. 2). After this, two different approaches were taken. In case of the "Tomba della Sirena", in order to preserve as much as possible the original details of the surface, the original 3D model created with Agisoft Photoscan and MeshLab was modified and sculpted in open source software Blender. In case of the "Tomba dei demoni alati", the pediment is preserved in three fragments with a large empty space between each other; for this reason we added a new mesh to the three fragments and sculpted only the new mesh in Blender. In this way we created the aforementioned partial reconstruction that displays the difference between the original and newly-added part.

The surface of the mesh of the "Tomba della Sirena" was smoothed to close holes, cracks and natural holes of the tuff rock. As a matter of fact, in several tomb façades of Sovana, traces of stucco and paint, that also gave the protection to the soft tuff stone, were found (Barbieri 2015). In this virtual reconstruction we suppose that also the surface of the "Tomba della Sirena" has been originally more smooth (and could be covered in stucco and painted, although there is no evidence), thus the surface of the 3D model has been smoothed (Fig. 3). During the sculpting process, the model has been repeatedly remeshed in MeshLab in order to close holes in geometry and make polygons more regular. After the sculpting phase, we created the new texture. Since the original model still had too many irregularities and a very complicated geometry, it was not possible to perform unwrapping. So, we had to simplify the geometry and experimented a retopology technique (Fitzpatrick *et al.* 2016). This way, the new model preserves the general shapes of the original one but is more regular and has a simple geometry. Unfortunately, it was not possible to do it automatically or semiautomatically, so the new model was created by placing every single new vertex manually on the surface of the original model following its shape in order to create regular web of square faces. The new model (7.51 MB) is much easier to manage by computer than the former (53 MB) and we can use it for building the texture by unwrapping its surface. However, before unwrapping, the model has to be subdivided into smaller sections according to the main iconographical features. Finally, the texture of each section, separately unwrapped before, can be imported in Adobe Photoshop and painted.

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ABSTRACT

This paper reports an aspect of the on-going project of my dissertation thesis at the Institute for Classical Archaeology at Charles University in Prague and concerns the application of multi-image photogrammetry technique in the documentation of the Etruscan rock-cut tomb façades. Etruscan rock-cut tombs with decorated façades are located in the inland area of Southern Etruria (currently Tuscany and Lazio, Italy). This paper focuses on the architecture of the tombs dated to the Hellenistic period (from the 4th century BC to the end of the 3rd-beginning of the 2nd century BC), when a significant change in architecture of the tombs took place. The aim of this paper is to show how 3D models acquired with the multi-image photogrammetry technique can serve as a tool for the archaeological analysis of the tomb façades. The acquired data and 3D models can be used for the documentation and digital preservation of the tomb decorations, which are exposed to heavy erosion mainly caused by water and vegetation. This paper also explains how acquired data can serve as well for the creation of the virtual reconstruction and virtual anastylosis of the tomb façades with missing fragments of decorations or fragments scattered around sites or in museums.