Etruscans in 3D
- Surveying and 3D modeling for a better access and understanding of heritage -

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Resumen

La documentación digital arqueológica en 3D de monumentos y yacimientos históricos es una valiosa fuente de información, muy útil tanto para la preservación y conservación, como para la restauración y reconstrucción del Patrimonio Cultural. En este artículo se expone el trabajo realizado en diferentes yacimientos del patrimonio etrusco, el levantamiento en 3D y el modelado de diferentes tumbas subterráneas decoradas con frescos (IV-VII a.C.), ubicadas en el centro de Italia. El proyecto "Etruscos 3D", nació con el objetivo de documentar (en formato digital), estudiar, analizar y conservar los diferentes monumentos y yacimientos del Patrimonio Etrusco, permitiendo un mejor acceso y comunicación de la información, así como crear contenidos digitales que sirvan para el desarrollo de exposiciones y visitas virtuales.

***Palabras Clave**: PATRIMONIO CULTURAL, LEVANTAMIENTO, MODELACIÓN 3D, ANÁLISIS, MUSEOS VIRTUALES*

Abstract

Archaeological 3D digital documentation of monuments and historical sites should be considered a precious source of information and it can be very useful for preservation, conservation, restoration and reconstruction of Cultural Heritage. This paper reports a work dealing with 3D surveying and modeling of different Etruscan heritage sites, featuring necropolis with underground frescoed tombs dating back to VII-IV century B.C., located in the area corresponding roughly to the actual central Italy. The project "Etruscans in 3D" was born with the aim of digital documentation, study, analyses and preservation of Etruscan heritage monuments and sites, but also to create digital contents for virtual visits, museum exhibitions, virtual and augmented reality, better access and communication of the heritage information.

***Key words**: CULTURAL HERITAGE, SURVEYING, 3D MODELING, ANALYSIS, VIRTUAL MUSEUM.*

1. Introduction

Protection of the existing Cultural Heritage from degradation or its loss is of vital importance. Nowadays the continuous expansion and development of new recording and visualization techniques allow us to obtain reality-based 3D models with high geometric accuracy and realistic appearance. The latest developments in 3D recording and modeling offer great potentialities for the accurate and detailed 3D documentation and digital preservation of existing tangible heritages and a large number of tools to make digital heritages more informative, easier to be visited and enjoyed even remotely. The data recorded in 3D can be used for several purposes, such as archaeological studies and analyses of architectural structures, digital documentation, preservation and conservation, 3D repositories and catalogues, virtual reconstruction, computer-aided restoration, virtual anastylosis, physical replicas, virtual and augmented reality applications, monoscopic or stereoscopic renderings, multimedia museum exhibitions and virtual visits, archaeological prospection, web access, visualizations and so on

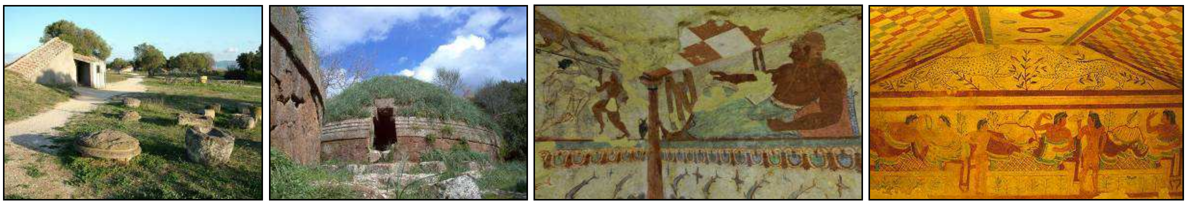

Figure 1. State of conservation of the Etruscan necropolis and frescoes in Tarquinia and Cerveteri (UNESCO World Heritage Site).

2. Reality-based surveying and 3d modelling

2.1 Data acquisition

The fieldwork was carried out during three campaigns between 2009 and 2011 in the main Etruscan necropolis (Tarquinia and Cerveteri – UNESCO World Heritage site since 2004 – Chiusi and Vulci) and museums (Chianciano and Rome). The Etruscan tombs (Fig.1) are fragile environments with forbidden access to preserve the internal conditions. Therefore the surveying had to follow strict rules and constraints, beside working in very narrow spaces often hard to access (Fig.2).

Approximately twenty underground tombs, most of them full of frescoes, were surveyed using photogrammetry and laser scanning (Remondino et al., 2011a). In addition, some artifacts located inside the museums were surveyed, too. 3D data were acquired by means of Time of Flight (TOF) and triangulation-based laser scanners as well as calibrated digital cameras. The 3D geometric models obtained using TOF scanners have typically a sub-centimeter resolution (5mm) while for the small archaeological finds, a sub-millimeter resolution was necessary (0.3mm). In order to create photo-realistic 3D models, high resolution digital images were mapped onto the geometries while IR and UV images where collected for diagnostics studies.

Figure 2. Surveying of Tomb of the Inscriptions, Vulci.

2.2 3D modeling

For each site and artifact, the most suited technique and geometric resolution were adopted, in order to assure the best results according to expectations and final use of the 3D model (Rizzi et al., 2011). The range-based datasets required alignment, merging, cleaning and hole filling procedures. In order to create a photorealist models (Fig.3), the tomb rooms were texture mapped with panoramic images.

The 3D models of the small museum objects (Fig.4) where instead textured using two different methodologies. The first one is a virtual projection onto the geometric model of a virtual image obtained by photo editing of a real object photo. The second method is based on the projection of some images aligned with the geometry by means of common points. A blending between the different texture is also necessary to achieve seamless results.

Figure 3. Geometric 3D model of Tomb of the Inscriptions.

Figure 4. Textured 3D models of artifacts collected in some Etruscan museums.

3. Archaeological and architectural analyses

The produced 3D models, being reality-based and photo-realistic, are a true digital representation of the heritage scenes and thus useful not only for simple visualization purposes but also for archaeological and architectural needs. Therefore the project became a multi-disciplinary work seeking communications between IT technicians and humanistic researchers in order accomplish their requests and necessities.

The geometric 3D models of the underground tombs were thus used for deep analyses on the architectural structures and geometric shapes. Indeed the precise measurements of such complex monuments are very interesting for archaeological studies, map production, analyses and investigations of the constructive methods and can be used to verify archaeological hypotheses or to formulate new ones (Fig. 5). A detailed 3D model definitely allows to produce either maps, plans, cross-sections, orthoimages or to calculate areas and volumes of excavations, visualize the inside and outside of the tombs or analyze every single geometrical structure.

The result obtained with classical surveying were compared with 3D model representations. The plans derived by old metric instruments are often subjective and affected by instrumental and operator errors. The geometric comparison between old plans and the new digitally-derived maps shows salient differences (Fig. 6). Reality-based 3D models can also be coupled with multispectral analyses for more deep and metric diagnostic studies e.g. of the frescoes.

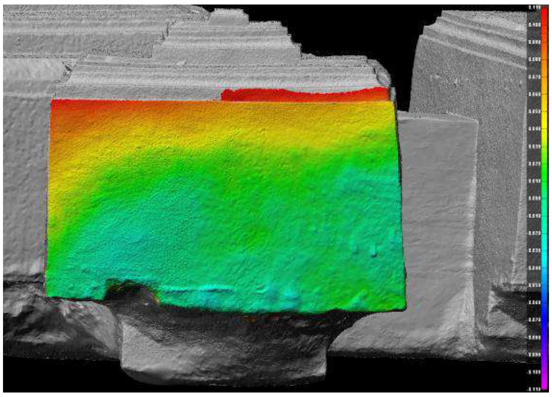

Figure 5. Geometrical analyses of the verticality of an inner wall of a tomb: there is a clear bending towards the inside of the room.

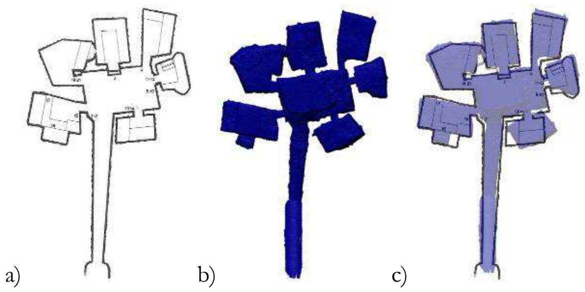

Figure 6. Tomb of the Inscriptions: comparison between the old map (a) and the newly generated with digital 3D recording (b).

The study of Etruscan paintings is indeed very important not only to chronologically distinguish the tombs from each other, find analogies and similar materials or study the depicted scenes through iconographic studies, but also for conservation or degradation analyses of the frescoes. Multispectral and multimodal images were thus acquired (Fig. 7) in order to identify some of the used pigments or highlight not any more visible elements (Remondino et al., 2011b). The basic idea of non-invasive analyses is to infer information exploiting the fact that materials reflect, absorb and emit electromagnetic radiation according to their molecular composition and shape. Thus visible multispectral imaging is normally used to measure (per pixel) the spectral reflectance of an artwork.

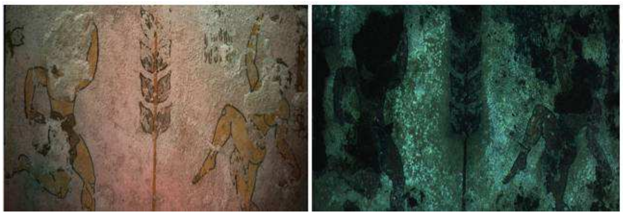

Figure 7. Composed IR false colour (left) and composed UV fluorescence image (right).

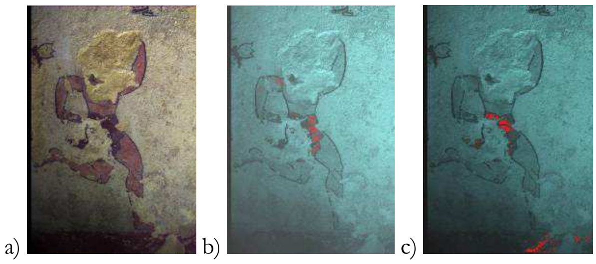

Figure 8. Etruscan fresco seen in the visible domain (a) and after the analysis of the multispectral data, which revealed an original red colour (b) and a later one, probably added during an old restoration (c).

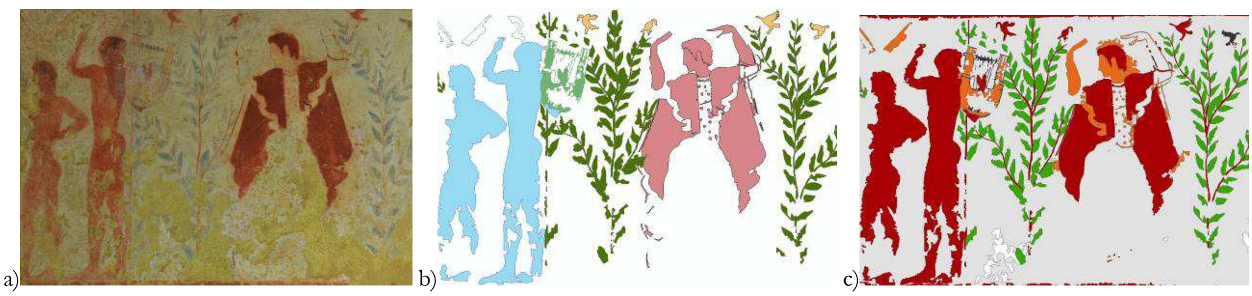

Figure 9. Orthoimage of a painted wall in the Bettini Tomb (a) and vectorialization of the frescoes for diagnostic and conservation purposes: classification according to figures and objects (b) or pigments (c).

Once all the multispectral images are registered, they can be overlapped in order to create a kind of image tensor. This tensor of information can be used to classify the imaged areas and recognize

occurring materials by producing the reflectance and fluorescence spectra for each single pixel. Different materials, e.g. original or added later, will show different spectra. Data collected from each single pixel can be compared among each other and classified based on their similarities (e.g. using the Spectral Angle Mapper measure) (Pelagotti et al., 2008). Therefore areas having the same colour under visible light, but having a different chemical composition, can be in this way differentiated (Fig. 8).

Finally orthoimages were produced in order to extract different (metric) information classified in layers and useful for diagnostic purposes. A detailed classification of the different elements, materials and deteriorations of the painting and the structures is essential to perform a comprehensive analysis that can be useful as a basis for conservation and restoration (Fig.9).

4. Visualization and virtual access

Digital technologies, providing either 2D or 3D data, can be very useful for better visualization and easier access to heritage sites or virtual handling of artifacts (Fig. 10). Starting from the produced 3D models of the tombs, for example, rendering can be realized (in monoscopic or stereoscopic mode) to show areas generally not accessible / visible to the public. Using panoramic images, virtual tour applications can be realized to allow spectacular walkthrough of the heritage sites and access to the underground frescoed tombs (Fig. 11).

In the "Etruscan in 3D" project, all these products were employed as multimedia contents for innovative museal exhibitions (Brussels, Trento and currently in Stockholm).

5. Conclusions

The article reported the ongoing "Etruscan in 3D" project which is aiming at the reality-based digitalization of different Etruscan masterpieces for conservation, preservation, restoration policies, multimedia and educational purposes, archaeological and architectural studies as well as virtual visits, better access and communication of the heritage sites. Thanks to the project, new tools and algorithms were investigated, a 3D recording and modeling methodology was optimized in order to allow an accurate and detailed 3D surveying that has proved to be very useful for archaeological studies, analyses and investigations and that can be used to validate archaeological hypotheses. The archeological studies rely now on metric measure, proportion, orientation and not on the base of many historical hypotheses or inaccurate old surveying. Based on the latest developments in the ICT and Geomatics fields, innovative applications and studies in the heritage field are therefore possible, also for the future of museums and possibly to prepare better conservation and preservation policies

Figure 10. Further products of the 3D modeling project: multimedia exhibition (above) and augmented reality platform for virtual access to museal artifact (below).

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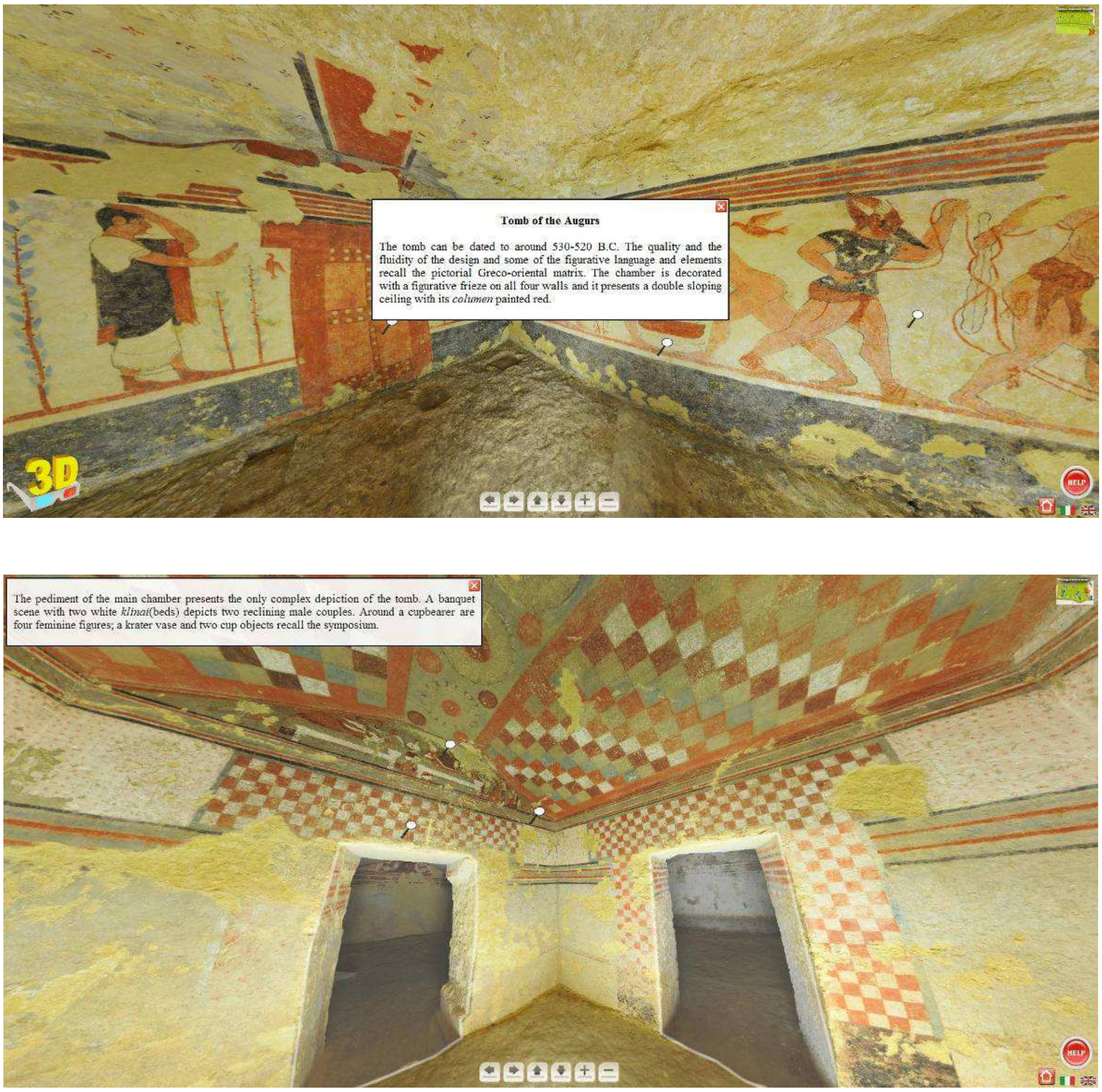

Figure 11: Virtual tours of the Etruscan necropolis to allow access to hidden heritages and spectacular frescoes monuments.

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