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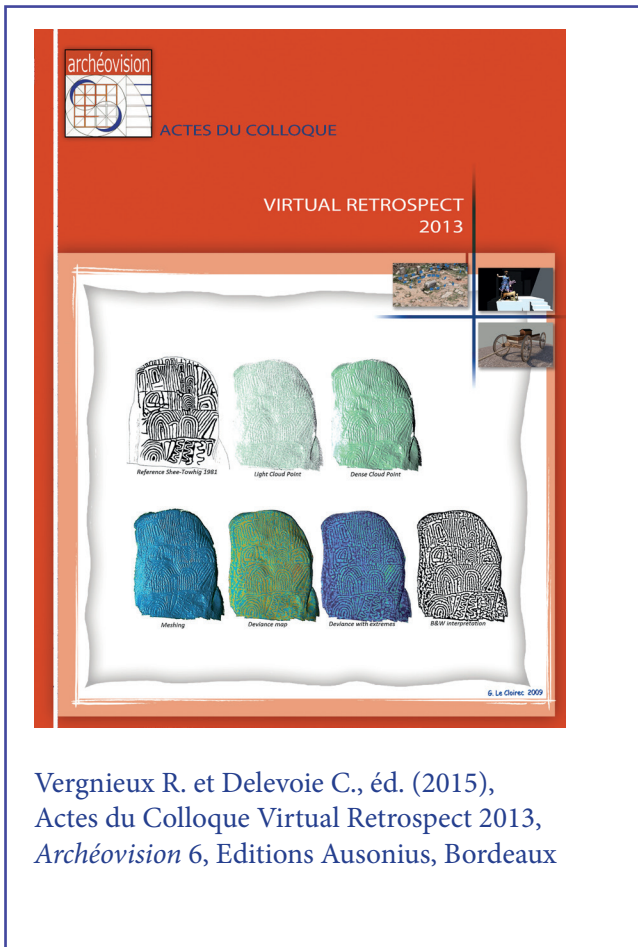
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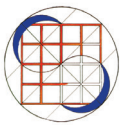
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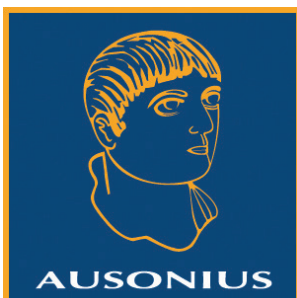
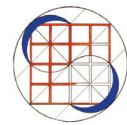
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# Methodology for sustainable digital restoration

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**Résumé :** La restauration numérique est une méthodologie centrée sur l'étude de l'objet, sur la restitution de son aspect esthétique original et de sa re-contextualisation. Il est situé entre la numérisation et la reconstitution virtuelle et vise à la reconstruction de l'aspect d'origine d'un objet à l'aide de technologies de l'infographie. Il peut être utilisé comme un support pour différents types de projets de recherche et ses résultats sont des excellents instruments didactiques dans la communication de l'œuvre au public. Afin de rendre la restauration numérique durable, les résultats et la méthodologie employée doivent être documentés et communiqués d'une manière complète et exacte. Cet article se concentre sur les meilleures pratiques de la restauration numérique et sur les méthodes de documentation et de communication des résultats.

**Mots-clés :** restauration numérique, documentation, diffusion, durabilité

**Abstract :** Digital restoration is a research methodology that focuses on the study of the object, on the restitution of its original aesthetic aspect and on its re-contextualisation. It is situated between digitisation and virtual reconstruction and aims at the restitution of the original appearance of an object by using computer graphic technologies. It can be used as a support for different kind of research projects and its results are excellent didactic instruments in the communication of the artwork to the public. In order to make digital restoration sustainable both the results and the methodology employed need to be documented and communicate in a complete and accurate way. This article focuses on the best practices of digital restoration and on the methodologies of its documentation and communication.

**Keywords :** digital restoration, documentation, dissemination, sustainability

In the past years many efforts have been done in order to ensure the intellectual and technical rigour of the digital visualisation of cultural heritage, with the consciousness of the increasing importance of new technologies for the study and the dissemination of cultural content.

Many of the projects that have been carried out with the goal to study and visualise cultural heritage objects or sites faced the problem of digital restoration. Therefore, the necessity to establish clear principles and best practices about performing and documenting digital restoration is a consequence of the willing to establish scientific rigour in digital reconstruction.

Digital restoration is the scientific process of studying and reconstructing an object by the means of computer graphic technologies: it is situated between digitisation and virtual reconstruction. In most cases it is part of the virtual reconstruction effort and has the goal of visualising the original aspects of the object in order to make it more understandable and enjoyable to the audience.

Like physical restoration, digital restoration is based on the extensive study of the object (material and structural aspects) and its context from historical, stylistic and iconographical point of view. It needs a multidisciplinary approach and a full documentation. But, where the physical restoration has the primary goal in the preservation of the object, digital restoration is primary focused on the study of the object, on the restitution of its original aspect and on its re-contextualisation.

For this reason, digital restoration provides an additional layer of information about the object. It can be used both as a research tool and as decision tool in projects. The process of digital restoration, for example, can be used in the preliminary phase of the physical restoration as an instrument to summarise and visualise all the knowledge about the object, in order to prepare and test the best restoration strategy.

It is also an excellent support to convey the object to the audience, especially in those situations where the object itself is in poor state of conservation or it is no longer available to the public due to its preservation needs.

This is for example the case of the cave of Santimamiñe<sup>1</sup> in the Basque country (Spain). The walls of the cave are decorated with almost one hundred paintings, drawn with charcoal or engraved on the rock, which are attributed to the middle stages of the Magdalenian period (approximately between 14 500 and 12 000 years ago). The delicate state of these paintings and the number of visits they had since they were discovered in 1916 impose the drastic decision to stop the access of the public to the cave, in order to better control the optimal environmental parameters for their preservation. The cave had been scanned and replicated in a detailed 3D model and the paintings are shown to the public in the visitor center of Santimamiñe in a digitally restored way (fig. 1,

2). The colors that faded away have been improved and the engraved signs are accurately displayed. In this way all visitors, including old and disabled people, can discover and enjoy the paintings in a comfortable and safe way, while their survival is safeguarded (fig. 3).

The most common techniques of digital restoration include the use of *depth maps*, of *digital sculpting* on the digitised 3D models or *3D modelling*.

The *depth map* of an object is a *BW* image that contains information relating the distance of its surface from a reference surface. The *depth map* of a surface contains all the spatial information needed to create a *normal map* or a *displacement map*. The *normal map* is an *RGB* image that intends to create the illusion of 3D surface detail when visualising the object. It contains for each pixel the direction of its normal. By reading the percentage of each colour in the pixel, the software knows the orientation in space of the local surface and is able to simulate that local detail. *Depth maps* can also be used as *displacement maps* to create more detailed 3D objects. In this process each point of the surface is displaced from its initial geometric position according to the black and white value of the displacement map.



Fig. 1. Santimamiñe virtual cave with wall paintings (image by VirtualWare).

1. Website of Santimamiñe cave: <http://www.santimamiñe.com/en/>

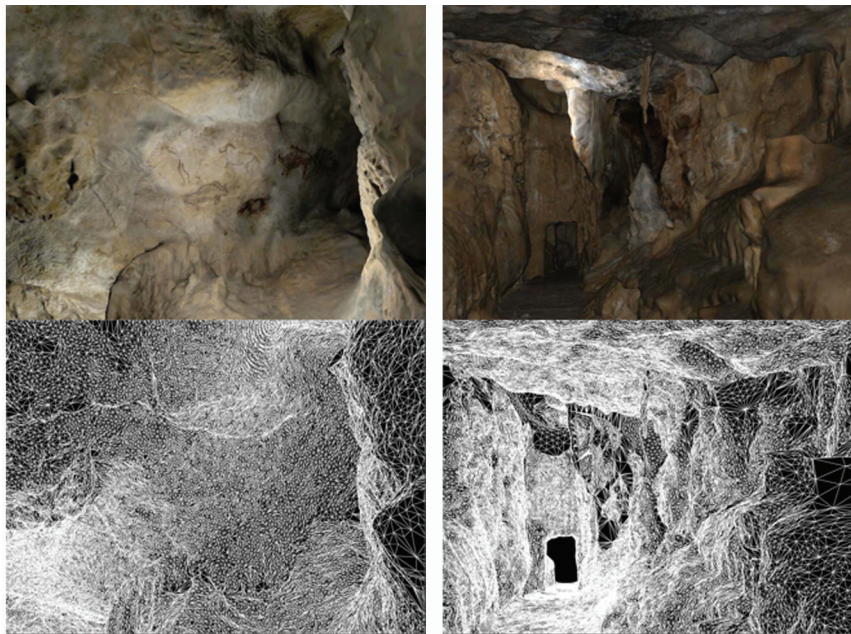


Fig. 2. 3D model obtained with laser scanning (images by VirtualWare).



Fig. 3. Santimamiñe visitor centre, virtual tour.

When the conditions of the object are good enough to be digitised, it could be easier to restore its scanned 3D shape. Thanks to the use of appropriate softwares like Sculptis, ZBrush or Blender it is possible to manipulate the 3D model in a way that closely mimic the intervention on a real object, although the result is beyond what is permitted by conservation ethic.

On the contrary, when the object is in extremely poor conditions of conservation, its original shape can be brought back only by completely model it in 3D. The reconstruction can be a very powerful tool to understand the nature of an object and its function, by simulating its use in a 3D model.

All these techniques had been employed in the frame of Etruscanning 3D European project, that aimed at the reconstruction of two etruscan tombs of the VI<sup>th</sup> century BC (fig. 4). The first tomb that had been studied



Fig. 4. Regolini-Galassi tomb, digital restoration of a patera. 1 the patera; 2 drawing by Luigi Grifi (1841); 3 digital restoration of the decoration (2011); 4 depth map; 5 3D digitally restored patera.



Fig. 5. 3D reconstruction of the Regolini-Galassi tomb.

and reconstructed was the Regolini-Galassi<sup>2</sup>, placed in the necropolis of Cerveteri, north of Rome. The reconstruction aimed at bring back together the grave goods, today preserved in the Vatican Museums, the actual tomb and the scholars' interpretation of the remains (fig. 5).

The tomb was excavated in 1863 with very little technical documentation, but some interpretative drawings were made by Luigi Grifi to display the position of the objects. The analysis of the remains, their reconstruction and their digital restoration led to a new discussion and interpretation.

The result, a 3D reconstruction that can be explored thanks to a natural interaction application, is now permanently on display in the Vatican Museums close to the real objects. Thus the reconstruction was not only a valuable research support, but also an excellent didactic instrument (fig. 6).

The second studied and reconstructed tomb was the Monte Michele n. 5<sup>3</sup> of Veii, close to Rome. The aim of this project was to re-contextualise the grave goods now on display in the National Etruscan Museum of Villa Giulia (Rome) and to show to the public, in a virtual way, the archaeological site and the process of archaeological survey explained by the archaeologist who lead it.

The structure of the tomb was reconstructed based on the laser scanning of its remains. Objects have been digitised, when in a good state of preservation, or 3D reconstructed. Then they have been digitally restored, in order to show to the public how they should have looked when placed in the tomb (fig. 7, 8).



Fig. 6. Etruscanning setup at the National Museum of Antiquities, Leiden (Netherlands).

The result of this project was not a 3D reconstruction of the tomb how it should have looked at the moment of its closure, but three different layers of reconstruction to display the position of the finds in the tomb, the process of their excavation and their interpretation. The application is permanently on display in the National Etruscan Museum of Villa Giulia, next to the glass case containing the grave goods.

When a project involving digital restoration and 3D reconstruction began, it is important to remember that the visualisation of the original appearance of the artwork has an enormous communicative power. Therefore, it is absolutely necessary that this operation is being performed with the maximal scientific accuracy. To ensure the intellectual and

2. Pietroni *et al.* 2012.

3. Adami *et al.* 2013.



Fig. 7. Monte Michele n.5 tomb, digital restoration of the cinerary urn. 1 remains of the urn; 2 3D digitally restored urn; 3 Depth map.



Fig. 8. Virtual reconstruction of the funeral chariot of Monte Michele tomb n. 5.

technical rigour of digital heritage visualisation, several principles have been stated in the London Charter.

It is very important to document each phase of the interpretative process, in order to achieve the maximal transparency and allow a broader discussion on the decision that have been taken. To make the process sustainable, is then necessary the optimal communication of the results and the methodology employed<sup>4</sup>.

Data concerning the digital restoration of an artefact should be available for the general audience in order to create a wider consciousness of its technical characteristics and of its importance, and to convey in a visual way the amount of knowledge related to it.

In this sense, powerful tools of communication are blogs. They allow a worldwide visibility and can be easily reached through a simple on line search.

A successful example is the blog on the Regolini-Galassi tomb<sup>5</sup> project, where the process of interpretation and reconstruction of the archaeological site is recorded. Posts have been written regularly during the duration of Etruscanning project, showing and documenting the evolution of the interpretation of the objects and their digital restoration. The blog gives also information concerning activities and events related to the Regolini-Galassi tomb, such as exhibitions in which it is displayed and public presentations. It continues to be updated also with related activities.

The blog collected, until the end of March 2014, about 50 000 views, with an average of 1500 visits per month. It attracts mainly university students while it saw only few reactions from scholars, possibly because blogs are not yet seen as suitable tools for a scientific discussion.

Encouraged by the success of the Regolini-Galassi blog, a second blog has been opened to show the evolution of works on Monte Michele n. 5 tomb<sup>6</sup>.

In order to provide a valuable documentation of a digital reconstruction, four steps have to be considered :

- sources have to be documented and assessed in order to understand their reliability ;
- they have to be correlated to draw conclusions from the correspondences, differences and inconsistencies between them ;
- a hypothesis tree have to be created in order to easily evaluate and choose the most probable hypothesis ;
- finally it is fundamental to make these information accessible together with the visualisation<sup>7</sup>.

Tools used for the documentation need to be open and easy to use, in order to be accessible also to non technical users. They can be simple text files, organised in a wiki structure, in

blogs when created to reach a broad audience, or in 3DPDF when addressed to a specialised audience.

The process that should be employed to document digital restoration is not different from the one shown for virtual reconstruction. Documentation, indeed, should bridge all the available knowledge related to the object and for this reason it is addressed to different type of audiences, such as scholars, student or museum visitors.

It is important that it addresses each kind of audience with a specific language and possibly with a diversity of accesses and visualisation channels.

In order to recognise the use of digital restoration as a research methodology it is important that both conservators and museum managers get to know its processes and its potentialities. Therefore, it is desirable to have an increase of the number of successful projects in which digital restoration is employed, and consequentially, an increase in the number of scientific publication that describe methodologies and results.

Results of projects involving digital restoration should be stored in central repositories not only to be preserved, but primarily in order to be consulted, discussed, studied and re-used. Metadata on the procedure are therefore essential and should be provided and stored together with the 3D model.

To conclude, we want to restate the role of digital restoration in giving a second life and a deeper meaning to objects that have lost their original context, as it is a crucial activity next to digitisation and virtual reconstruction. Moreover, we want to stress the concept that the integration of 3D models and metadata concerning their creation and the widespread diffusion of these information make the 3D model sustainable. We hope that museums and cultural heritage sector will overcome their inertia in accepting new technologies and will start to employ more and more digital restoration and 3D reconstruction as support in understanding their objects.

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