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UNVEILING *DAMNATIO MEMORIAE*. THE USE OF 3D DIGITAL TECHNOLOGIES FOR THE VIRTUAL RECONSTRUCTION OF ARCHAEOLOGICAL FINDS AND ARTEFACTS

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Abstract:

In ancient Rome, *damnatio memoriae* was a practice of erasing the memory of condemned persons from historical records after their death. This practice was usually addressed by the Senate to Roman elites and emperors who were declared enemies of the State, in order to preserve the honour of Rome. This condemnation usually included practices such as, for example, the erasure of names sculpted on inscriptions and the destruction or reworking of statues and of any other image of the person. Emperor Nero, for example, was condemned to this practice immediately after his death and a wide iconographic repertoire on him was therefore destroyed or deeply damaged. This lack of information can actually be improved thanks to the possibilities of virtual restoration and reconstruction offered by 3D digital technologies.

The aim of this paper is to show how the possibility to acquire 3D reality-based data from archaeological finds allows experts to build 3D digital models that can be analysed and managed in a virtual environment and can be relocated, assembled or restored in order to suggest or graphically support archaeologists' interpretations and reconstructions. The paper shows the methodology developed for the virtual restoration of a statue of Nero starting from the 3D digitisation of the torso that was found 500 years ago near the Roman theatre of Bologna, Italy, the ancient Bononia.

Key words: 3D reality-based survey, 3D sculpturing, 3D modelling, virtual reconstruction, virtual archaeology, Nero

1. Introduction

In the last two decades, the widespread use of 3D digital technologies in the cultural heritage field is offering scholars new opportunities to improve the quality of graphic representations used to describe the results of their investigations. These improvements are mainly due to the effective communication power of images and graphic simulations that facilitate the transferring of information to a wide range of audience. Digital illustrations can therefore be used in different contexts and with different purposes, ranging from multi-resolution documentations to virtual restorations and reconstructions.

In addition to this aspect, since vision has always influenced the way we understand reality, the possibility to manage its replica in a digital environment allows scholars to conduct cross analysis of data and to verify their interpretations through the manipulation of spatial information and through simulations.

This aspect has sensibly improved the possibilities to exchange information between different disciplines, with evident benefits in knowledge sharing and in scientific research. 3D digital representations can therefore be considered as powerful knowledge tools, as well as effective communication instruments.

The aim of this paper is to show how the use of 3D digital technologies can help to reconstruct past scenarios and sites. In particular, the paper shows the results of investigations held on a Roman statue that was both intentionally and accidentally damaged during the past centuries.

Sculptures can be considered as interesting and rich fields of investigations, since beside their evident communicative intent, they are the representation of a specific cultural and historical context. The understanding of representation codes that is possible to recognize within sculptures can therefore help their dating and, moreover, the reconstruction of wider historical contexts.

Fifteen years ago, the use of 3D digital technologies for the high resolution 3D survey of Michelangelo's David statue represented a pionieristic project in the field of documentation of Cultural Heritage (Levoy et al., 2000).

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Figure 1: Pictures of the torso of Nero (Archaeological Museum of Bologna): a) The entire torso; b) Details of the decorated armour; c) Chisel marks that testify the intentional detachment of the head.

Since that project, range and image-based technologies have been widely used in this field and in particular in archaeological contexts and sites to build digital 3D models of artifacts and finds from reality-based data (Barceló, 2001; Guidi et al., 2002; Velios & Harrison, 2002; Böhler & Marbs, 2004; Guidi et al., 2009; Forte, 2011; Manferdini & Remondino, 2012; Scopigno, 2012).

Several projects concerning the virtual restoration and reconstruction of statues were recently started with different purposes, ranging from the experimentation and integration of different survey and 3D modelling techniques, to the collection of 3D models to be used inside architectural contexts in order to add detailed information to wider virtual architectural and urban reconstructions. The Rome Reborn (Frischer, 2008), the Digital Hadrian's Villa Project (Frischer & Fillwalk, 2012), the reconstruction of the East pediment of the Temple of Zeus at Olympia (Patay-Horváth, 2013) are just some examples of the integrated use of 3D models of statues and architectures at different scales of complexity.

Other projects on the digitization of statues were recently started with the aim of populating 3D data-bases to share information among different scholars and institutions. The Digital Sculpture Project, for example, was developed in 2009 with the aim of overcoming the problem of huge computational costs required for the visualization of high-resolution 3D models of statues. In particular, within this project, a visualization tool was developed to display high-resolution renderings of complex 3D meshes on-line. This tool also allows the collection of different kinds of information pertaining sculptures that can be linked together through the use of 3D models. These last can be used, for example, as graphic interfaces where different information pertaing the geometry of statues and their original pigments can be overlapped.

In another context, image-based technologies and the possibility to acquire 3D data from uncalibrated pictures from different moments and survey conditions can be used to build up 3D models of cultural heritage. An example of an important heritage that was destroyed ten years ago can be found in Grün, Remondino & Zhang (2004).

In this context, the present paper shows the results of investigations conducted on a statue of Emperor Nero that was found in Bologna, Italy, five centuries ago and that was intentionally damaged after Nero was condammned to *damnatio memoriae* by the Roman Senate (Fig. 1).

This practice destroyed a wide iconographic repertoire on Emperor Nero. Nevertheless the Nero's statue can actually be recovered thanks to the integrated use of 3D survey and modelling tools that facilitate the combination of fragments from different finds and allow scholars to verify their interpretations, as well as to effectively communicate the results of their complex analisys.

2. The torso of Nero and its reconstruction hypothesis

The loricated torso attributed to Emperor Nero is one of the masterpieces conserved in the Archaeological Museum of Bologna. It was probably discovered in 1513 (Malvasia, 1690), or on December 1514 (Pasquali, 1621) and it is one of the best-known ancient archaeological findings in the city centre. It was unearthed while the foundations of a house were laid, on the northern side of Via de' Carbonesi, exactly in the same area where the retaining wall of the Roman theatre's cavea was excavated some years ago (Ortalli, 1986).

The statue, representing a male figure wearing military garments, is preserved to the height of 117 cm. It was defaced, lacking the head and the neck, which were taken away in a violent manner. The arms and the legs were lost too; only the stumps of the forearms and the upper part of the legs remain.

The figure leans on his right leg. Over the short-sleeved tunic, the man wears a two-sided muscle cuirass, or *lorica muscolata*, fastened by two leathered shoulder straps. On the shoulders and around its lower hem, the armour has short-fringed *pteruges* (leather or fabric strips) a second row of fringed *pteruges* extends to protect thighs. On the left shoulder, the *paludamentum* (a fringed cloak) is laid down. The remainders of the arms do not allow an unequivocal interpretation of their original position: the left arm was reasonably raised to hold a spear, whereas the right one did not lean along the flank, as most scholars suggested. In view of the slight inclination of the right forearm stump, the arm must have been stretched out forward, possibly to hold a *patera* or *phiale* for libations. On the front of the loricated armour quite a refined high-relief adornment stands out, representing a gorgoneion at the centre of the chest and two Nereids sitting on the back of two sea-dragons.

The first who recognized it as a statue of Emperor Nero was Guido Achille Mansuelli in 1956 (Mansuelli, 1959), and its attribution now seems indisputable. Firstly we must lay emphasis on the intervention of *damnatio memoriae* proved by the violent removal of the head; moreover, the torso was discovered near the theatre, which was increased and enriched with new ornamental apparatuses under Nero. In addition, the Emperor and his family had a particular tie with *Bononia*, which led him plead with the Senate for the allocation of ten million sesterces to the reconstruction of the city in 53 A.D. (Tacitus).

The exact dating of the sculpture is more arduous: it could have been made between 53 A.D., when Nero advocated Bononia's case with the Senate, and 60 A.D., when an honorary inscription was dedicated to Nero; this inscription was discovered near the theatre, and perhaps engraved to celebrate the completion of the restoration project.

The missing parts of the statue were borrowed from the Augustus of Prima Porta for the limbs – with suitable adjustments in view of the different position of the statue, especially its arms – and the marble portrait of Nero from Olbia.

In order to recreate the statue's limbs, our choice was inevitable, since we consider the Augustus of Prima Porta the earliest example of Roman Imperial loricated sculptures and fortunately have a twentieth-century copy of it, well preserved at the Museum.

Nevertheless, we encountered severer difficulties to find an appropriate head for the statue. If the statue's alleged date of creation is reliable, a head pertaining to the portrait of Nero Type 2 must be considered (accepting portrait typologies by Cadario 2011) juvenile and still related to the canons of Julio-Claudian portraiture in common use in A.D. 55 – or, least probably, to portraits Type 3, influenced by Hellenistic models in vogue since A.D. 59. Our choice therefore went to one of the earliest examples of portraits Type 2, which came from Olbia and is now preserved at the National Archaeological Museum in Cagliari (Fig. 2).

The Emperor still has a juvenile and yet non-idealised face, compared to his childlike portraits, with hollow features and the distinctive coiffure with longer hair and fringe combed clockwise over the right side of his forehead and counter clockwise over the left *("motivo a forcella"*).

Figure 2: a) Bronze copy of the Augustus of Prima Porta statue; b) Details of its legs (Archaeological Museum of Bologna); c) Nero's portrait from Olbia (National Archaeological Museum of Cagliari, Cadario 2011).

3. The adopted methodology

The virtual reconstruction of the statue of Nero required a series of preliminary analysis aimed at developing the most suitable methodology and the related technologies and procedures. In this phase, particular attention was paid to the selection of the level of detail of the digital 3D model of the statue, following communication aims and the geometric characteristics of the existing find. As a matter of fact, while the torso presents small scale details that can be accurately measured and surveyed, the 3D modelling of missing parts follows reconstruction hypothesis whose graphic representation could be left incomplete, as they are opened to different solutions. In other contexts, these reconstructions can instead be translated into spatial information that can derive similar geometries from elements selected within other archaeological finds. These latter can be acquired using different approaches and survey techniques. Afterwards they need to be manipulated in order to integrate different geometries and their level of detail.

In the case of Nero, the entire process was organized within three main phases: i. the accurate and detailed 3D survey of the torso; ii. the 3D sculpting of missing parts starting from geometries derived by other finds; iii. the integration of data collected within the previous two steps.

As far as the first step is concerned, the selection of the most suitable methodology was driven by the purpose of collecting the most accurate and detailed geometric information of the torso (resolution between 0.15 and 0.2 mm), in order to document its conservation conditions and also to provide a digital replica of the find. Within the whole process, the 3D acquisition of the actual radiometric characteristics of the find was not required, since the aim of our research is to virtually restore the whole statue and the chromatic characteristics it had before the damages inflicted by the *damnatio memoriae*. For this reason, a range-based approach was preferred over an image-based one.

The second step consisted in the detection of the most suitable methodology to adopt in order to easily and quickly derive the main geometric information from other finds related, for example, to the position of the limbs, to gestures, to the shape of the face, to facial features and to the hairstyle. In this case, image-based technologies were privileged over range-based ones.

The third step consisted in the manipulation of data acquired from other finds in order to adapt geometry, scale, spatial orientation and level of detail of face and limbs both to archaeologists' reconstruction hypothesis and to the replica of the torso. 3D sculpting techniques were adopted to modify surface geometries, to add detail, but also to manipulate the 3D model of the torso in small transition areas. For example, the mesh was entirely reconstructued around the neck, where the statue was damaged to remove the head, and in some small areas (i.e. on the armour) where some details were missing.

3.1. The high resolution 3D survey of the torso

The torso was surveyed using a triangulation laser scanner. Preliminary tests were conducted using a Konica Minolta Vivid 900. Acquisitions through tele lens highlighted noise problems due to the translucent characteristics of marble (Fig. 3). In order to overcome this problem a Konica Minolta Range 7 scanner was then adopted.

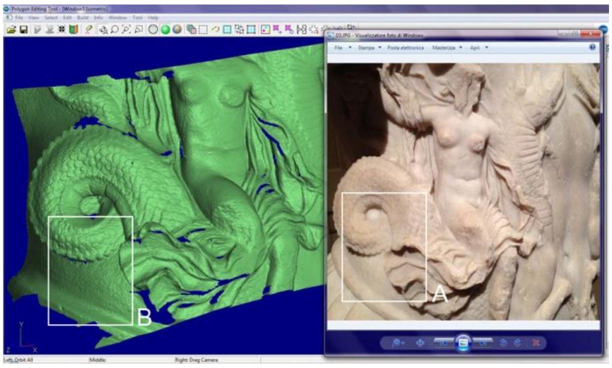

Figure 3: Digitisation of Nero's sculpture: A) Detail of the armour; B) The mesh acquired using a Konica Minolta Vivid 900 is affected by noise due to the translucent characteristics of marble.

During the survey campaign, some difficulties arose due to the large size of the statue and its immovable position compared to the dimensions of single scanning areas (Table 1) and to the possibilities to rotate and lift the laser scanner around the torso. For this reason, a sliding scaffolding was used and overabundant number of scans were captured.

Further difficulties were highlighted due to the geometric complexity of cloak and tunic (Fig. 4). As a matter of fact, these areas present deep convexities that are difficult to capture. In this case, redundant scans were captured and small lacks were manually closed during the post-processing of data.

Table 1: Main specification of Konica Minolta Range 7 laser scanner equipped with a tele lens, set on multi focus mode.

Specification	*mm*	*mm*
Measuring range	462	781
X-Y size	81 x 102	138 x 172
Accuracy (using a Konica Minolta two globes instrument)	± 40 µm	
Precision (Z, σ)	4 µm	

Figure 4: a) Details of the *pteruges*, of its geometrical complexity; b) Small scale details.

The survey of the whole torso required the capturing of 300 scans that were aligned, merged and topologically corrected in order to provide a 100 million polygonal mesh. This high resolution 3D model was afterwards decimated to a 25 million polygons mesh in order to be easily manipulated, while preserving its high artistic quality (Fig. 5).

3.2. The 3D survey of fragments from other finds

As already mentioned in Section 2, for the reconstruction of the shape and arrangement of legs and arms, the classical bronze statue of Augustus of Prima Porta was used as a reference. In this phase, since the main shape and orientation of limbs were required, different technologies were tested with the purpose of easily providing its 3D reconstruction. In particular, a Structure from Motion (SfM) approach was privileged.

The statue was acquired using a Nikon D90 camera equipped with an AF-S DX Nikkor 18-105 mm lens. Images were processed using a well-known pipeline and the tools integrated in the Agisoft PhotoScan package.

During the survey campaign some difficulties were highlighted due to the location of the statue and to the impossibility to capture images from the back and above the statue. Particular attention was paid to the illumination conditions, since the dark colour of bronze and shadows inside convexities could affect the detection of details.

Figure 5: a) On site survey of the torso using a Konica Minolta Range 7 laser scanner; b) Views of the decimated 3D model (up to 25 million polygons).

The survey was organized in two steps, aimed at acquiring the overall shape of the statue and its detailed elements. Different focal lengths were therefore used to capture images at different resolutions, in order to quickly provide the geometry of arms and legs and then orient them in the 3D digital environment using the 3D model of the whole statue as a reference. The meshes of limbs were afterwards manipulated in order to add missing details, such as, for example, wrinkles near articulations and nails (Fig. 6). Furthermore, other 3D sculpting tools were adopted to modify the arrangement and the overall shape of limbs. Details on the sculpting process will be presented in Section 3.3.

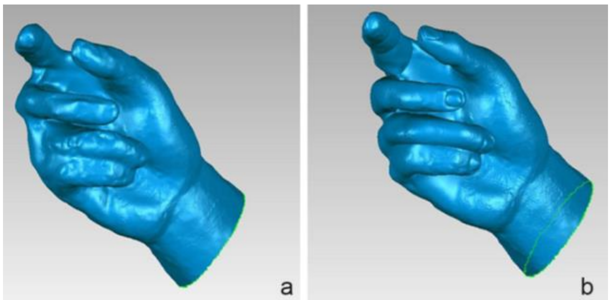

Figure 6: 3D model of the right hand: a) Derived by pictures; b) Improvement using 3D sculpting tools.

3.3. The sculpting of missing elements and the whole integrated 3D model

The reference portrait for the 3D modelling of the head was selected in the Nero's torso of Olbia that is actually preserved at the National Archaeological Museum of Cagliari.

The 3D model of the head was entirely sculpted inside a 3D digital environment using Pixologic Sculptris. This is a free software that was developed by Pixologic, the same company that one decade ago released ZBrush that actually represents the most widely-used digital sculpting application in computer graphics. Through the use of Sculptris, 3D models are created starting from a sphere of virtual clay that can be sculpted using brushes whose shape and stroke can follow the operator's needs.

In the case of Nero, features were sculpted through the detection of visual references on pictures of its marble portrait. This visual matching allowed the intuitive detection of symmetries and evaluation of sizes. Some details were afterwards modified in order to adapt features, build and hairstyle to the age of the torso, which is supposed to represent Nero at a more mature age with respect to the reference portrait (Fig. 7).

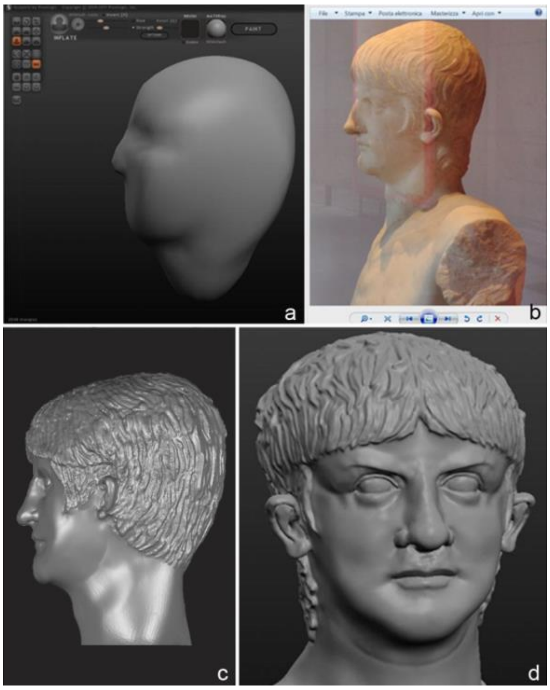

Figure 7: 3D sculpting of Nero's head. a) First steps using Sculptris; b) Picture of the reference portrait; c) Improvement of the profile; d) Final result.

The sculpted head was then scaled and oriented in the 3D environment together with other limbs, in order to align the models of the single elements to the torso. This process was firstly performed by manually selecting pairs of homologues points within the single 3D models and then iteratively adapting the size of head and limbs to the dimensions of the torso.

This step is rather crucial within the entire reconstruction process, since it can highlight inconsistencies, incorrect transitions and non-homogeneous surface finishing and level of detail that it is difficult to detect during the previous phases.

In the case of Nero, inconsistencies were detected, for example, near shoulders where portions of the cloak derived by the Augustus statue had to be removed and the articulation had to be manually rebuilt. Another crucial element was represented by the neck, where its bottom area was damaged by *damnatio memoriae* and therefore had to be manually rebuilt (Fig. 8).

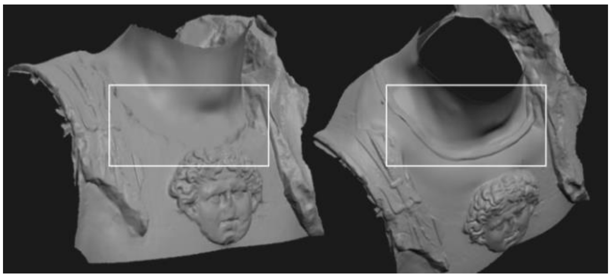

Figure 8: Reconstruction of the transition areas between the surveyed torso and the sculpted head.

4. Conclusions and future works

The present research shows how digital technologies can be used as effective tools able to support the work of archaeologists and art historians involved in the interpretation and reconstruction of history. As a matter of fact, the possibility to manage 3D models of finds in a digital environment allows experts to conduct cross analysis between different disciplines and to test reconstruction hypothesis through the manipulation of digital matter.

In addition to this aspect, this project shows how 3D virtual reconstructions can provide effective graphic representations that can easily and intuitively be used to communicate the results of deep and complex analysis and interpretations (Figs. 9, 10 and 11).

From an archaeological point of view, being able to communicate a plausible and probable reconstruction of the original look of the statue to a non-specialist audience represents a very important challenge and task. Educational and communicative potentialities are therefore remarkable.

From a scientific point of view, we are aware that no comparative reconstruction will ever return the original shape of the statue, because there is no trace of “those” specific faces and limbs, nor any other source is available to describe them precisely. This reconstruction of the sculpture can therefore be only one of the many possible reconstructions.

Nevertheless the model has an unquestionable documentary value and it also allows the combination of geometric 3D reality-based data with multispectral investigations aimed to identify ancient colours of the statue (Baraldi, Del Gallo, Marchesi, & Rossi, 2014). In this direction, investigations on the torso are actually being held in order to detect traces of pigments that are still present on marble. The results of these detections will lead to the overlapping of geometric and radiometric information and to the restoration of the ancient colours on the original parts of the statue.

This hypothetical reconstruction will offer to visitors (and maybe to specialits too) an immediate reading of the whole statue as it might have been in its original condition.

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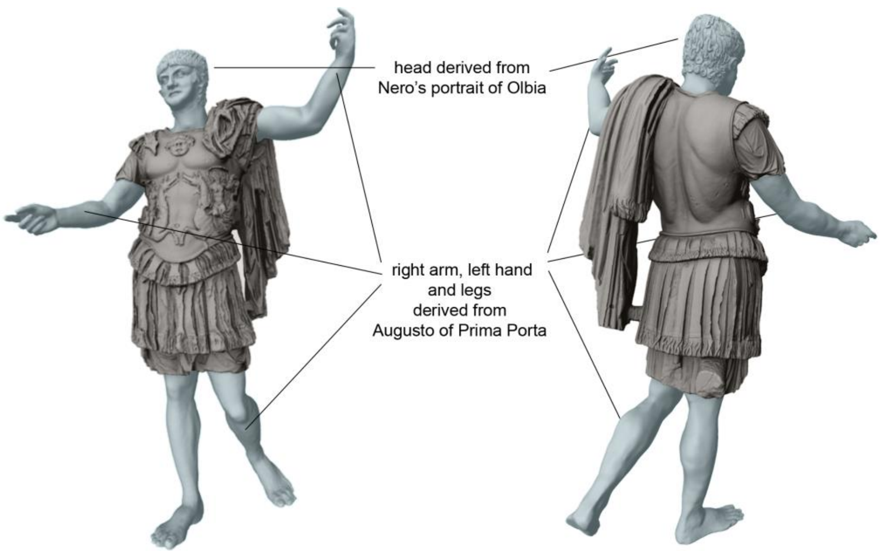

Figure 9: Integrated digital 3D model of Nero’s statue.

Figure 10: View of the 3D model of Nero's statue.

Figure 11: Details of the virtual reconstruction of Nero's statue.

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