AN EXPERIMENTAL WORKFLOW FOR THE VIRTUAL RECONSTRUCTION OF ANCIENT STATUES

Leonarda Fazio[a,*], Mauro Lo Brutto[b]

[a] Department Cultures and Societies, University of Palermo, Viale delle Scienze, Ed. 15, 90128 Palermo, Italy. leonarda.fazio@unipa.it

[b] Department of Engineering, University of Palermo, Viale delle Scienze, Ed. 8, 90128 Palermo, Italy. mauro.lobrutto@unipa

Abstract:

The work aims to investigate the main steps of a virtual reconstruction process of ancient statues, inspecting theoretical and technical approaches. Two fragmentary Roman statues from the "Sanctuary of Isis", inside the Archaeological Park of Lilibeo-Marsala (Italy), were chosen as a case study. Trying to preserve the original artwork authenticity and the transparency of the reconstruction method, a workflow was developed following three steps: 1) 3D survey and reality-based model production; 2) evaluation of reconstruction hypotheses based on a rigorous selection of reference sources; 3) 3D modelling and source-based model creation. Three models for multiple visualization purposes were carried out: a high-resolution reality-based model for documentation and detailed specialist analyses, a real-integrated model for scientific purposes in which it is possible to visually distinguish the surviving fragments from the modelled ones through a partial texture and an ideal model useful for dissemination aims with a uniform texture that simulates hypothetical original state of the sculptures.

Keywords: virtual reconstruction, Roman statues, 3D survey, 3D organic modelling, source-based model

1. Virtual reconstruction of ancient statues

Technological progress in 3D survey and computer graphics have opened new scenarios for cultural heritage enhancement. Among these, the virtual reconstructions (VR) of archaeological buildings and artefacts offers a strategical opportunity for knowledge dissemination.

The London Charter (2009) and The Seville Principles (2011), which define the scientific principles for cultural heritage visualization in virtual environment, provide general guidelines but no prescriptions or standards to guide the VR practitioners. To fill the gap especially in the well-established scientific field of architectural VR, different codes and standards were developed taking inspiration from museum standard (Kuroczyński, 2017), physical restoration or archaeological practice (Demetrescu, 2015).

Developed methods and guidelines highlight the transparency of a reconstruction process and the use of reliable information sources as essential scientific values to minimize arbitrariness in a VR process. Most of the archaeological monuments or artefacts, in fact, come to us lacking. In these cases, interpretation and consequently reconstruction (physical or virtual) must make use of sources of information - e.g. descriptions, drawings, or comparisons with similar specimens - to recreate their original state. Often, sources are also lacking, involving a greater inventiveness effort, for example, to recreate a complex building as it was in historical reality starting from poor archaeological remains.

A particular case of VR concerns ancient sculptures. For Greco-Roman statuary, the reconstruction may take advantage of a detailed sample of iconographic models and variants for multiple purposes. Specimens' comparison allows formulating more scientifically reliable hypotheses on VR of fragmentary statues. At the same time, different documents (photos, drawings or 3D models) can be used as references to support the 3D modelling.

A 3D product of a reconstructed statue can achieve a very high level of realistic representation, re-creating the space, shapes and colours to simulate and emphasize the visual experience. VR of statues was employed for scientific or educational purposes, in diagnostics and restoration (Bagnéris et al., 2017), for knowledge and dissemination aims, producing physical (Fregonese et al., 2019) or digital models (Bennoui-Ladraa, Chennaoui, & Ainouche, 2020) following reconstruction approaches and methodologies formulated for each specific study case. However, without effective sources of information to support VR and using an arbitrary reconstruction process, the final model could be very different from the historical reality of an artwork. Variables such as shape, size, colour can suffer significant changes during different steps,

---

* Corresponding Author: Leonarda Fazio, leonarda.fazio@unipa.it

compromising the transparency, as well as the scientific value of virtual reconstruction.

The work aims to investigate the main phases of a VR process for ancient statues, evaluating theoretical and technical aspects in order to assess a suitable workflow for different aims and levels of visualization, trying to preserve the authenticity of the original artwork and its surviving fragments.

2. The case study: *Aesculapius* and *Hygeia* statues from *Lilybaeum*

The "Sanctuary of Isis" is the only one known sacred area of the ancient Hellenistic-Roman city of *Lilybaeum*, today's city of Marsala (Italy). Archaeological excavations conducted in 1988 and 2008 have brought to light a temple stands inside a sacred space. Two main phases of the building are known: the first (2nd century BC), of which few traces are survived, and the second (2nd – 4th century AD), best preserved, with the main room decorated by a polychrome mosaic with geometrical motifs. Few archaeological evidence suggests that the temple was dedicated to Isis, as proves a small column with a dedication to the *myrionimos* (thousand names), epithet of the Alexandrian goddess (Giglio Cerniglia, Palazzo, Vecchio, & Canzonieri, 2012).

One of the main goals of the researches promoted by the University of Palermo inside the archaeological Park of *Lilybaeum*, aims to increase site attractiveness and the study of the sacred area through VR approaches. Until now, activities have produced detailed documentation of the preserved architectural remains integrating range-based and image-based techniques (Ebolese, Lo Brutto, & Dardanelli, 2019) and a 3D partially reconstruction of the building (Lo Brutto & Fazio, 2020). A significant rule in the project is the interior design reconstruction, with stucco frames decorations on the roof, polychrome marble on the walls, ornamental columns and several sculptures specimens survived fragmentarily. Among the fragments recently exhibited in the Archeological Museum of Lilibeo, two life-size statues stand out, whose iconographies correspond to *Aesculapius* and *Hygieia* (Fig. 1), medical and healing deities of the Greek and Roman world. Based on the excavation data, both statues should be placed in the mosaic paved room, probably on top of a small podium.

3. Workflow

The main steps of the VR workflow are (Fig. 2):

1) 3D survey and reality-based model creation;
2) Evaluation of reconstruction hypotheses and selection of sources/references;
3) 3D modelling and source-based model creation.

As in restoration practice, VR process should use tools and techniques that do not physically alter the structure of an object, preserving its authenticity. State of conservation of the monument, dimensions and type of material, ambient lighting conditions, are thus all aspects that must be taken into account choosing the right technique of survey.

Different 3D survey methods (range-based and image-based techniques) were adopted for step 1 (reality-based model creation). Generally, laser scanners allow good

geometric accuracy, but a low-quality texture, unlike photogrammetric ones. For this reason, two techniques were integrated.

Figure 1: The fragments of the statues of *Aesculapius* and *Hygieia/Salus*.

Firstly, the Stonex F6 portable 3D laser scanner was used. The instrument enables to capture medium-large objects 3D models in dynamic motion. 3D scans of *Aesculapius* and *Hygeia* statues and further smaller fragments were acquired. The survey was conducted in a controlled indoor environment, monitoring every acquisition step in real-time through a tablet. Echo software was used for noise removal, editing, registration corrections and meshing of the 3D data, obtaining 3D models with a mesh of about 850,000 faces for the *Aesculapius*'s statue and about 940,000 faces for *Hygieia*. Data checking highlighted low output quality texture, especially for smaller fragments.

Figure 2: Workflow of *Aesculapius* statue VR.

Then, a close-range photogrammetric survey was carried out on the same fragments. Images were acquired with a Nikon D5200 digital camera, equipped with 24-55 mm lenses and a resolution of 6000 x 4000 (pixel size 4.05 x 4.05 μm). For the statues of *Aesculapius* and *Hygieia*, a total of 55 images and 48 images respectively were taken. Images were processed with Agisoft-Metashape version 1.5.0. Image orientation was automatically computed by

the software; a dense point cloud and a textured mesh were generated.

In order to obtain a correct overlap between laser scanner and photogrammetric 3D models, the photogrammetric one was scaled according to the size of laser scanner model (Fig. 3); a unique reference system was then assigned to both 3D models.

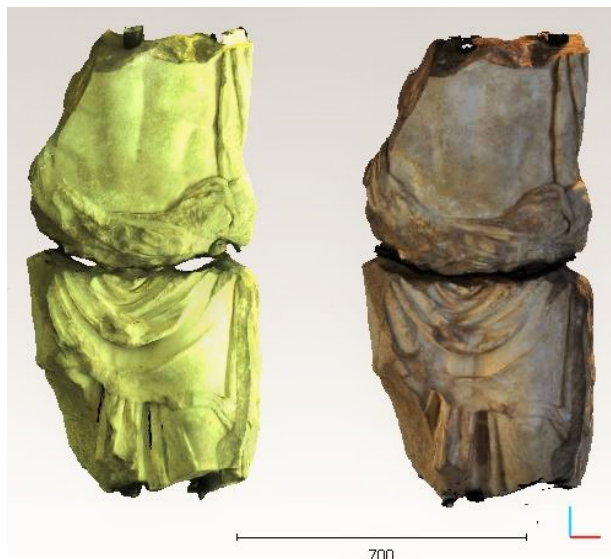Currently, steps 2 and 3 were only performed for the statue of *Aesculapius*.

Figure 3: Laser-scanner 3D model (left) and photogrammetric 3D model (right) of the *Aesculapius* statue.

The second step of the workflow concerns sources and the assessment of reconstructive hypotheses on the missing parts. In order to define the whole 3D geometry of the statue, its 3D reality-based model was compared to a set of typologically similar statues of the same period; one of these was chosen as reference in the modelling phase.

In the third step, the reality-based model was first imported into the virtual workspace of Autodesk-Maya and then modelled integrating missing anatomical parts according to the information obtained by the image reference (2D source). In addition, a small fragment of the foot belonging to the statue, previously surveyed, was integrated. Further 3D sources (such as the 3D model of a *Serapis* head) were used to recreate some problematic elements in organic modelling. The obtained source-based model was finally refined in Pixologic-ZBrush, which allows a more realistic rendering for visualization purposes.

Further processing will be performed on the *Hygieia* statue, improving and verifying the experimental workflow, and developing an infrastructure for the AR / VR visualization of models.

Acknowledgements

References

Bagnéris, M., Cherblanc, F., Bromblet, P., Gattet, E., Gügi, L., Nony, N., Mercurio, V. & Pamarta, A. (2017). A complete methodology for the mechanical diagnosis of statue provided by innovative uses of 3D model. Application to the imperial marble statue of Alba-la-Romaine (France). J*ournal of Cultural Heritage, 28*, 109–116. http://dx.doi.org/10.1016/j.culher.2017.05.002

Bennoui-Ladraa, B., Chennaoui, Y. & Ainouche, H. (2020). The virtual archaeology and interpretative process: Case study of the virtual reconstitution of a Hercules marble statue from the nameless temple of Tipasa. Digital Applications in *Archaeology and Cultural Heritage, 19*, 1-10. https://doi.org/10.1016/j.daach.2020.e00163

Demetrescu, E. (2015). Archaeological Stratigraphy as a Formal Language for Virtual Reconstruction. Theory and Practice. Journal of *Archaeological Science, 57*, 42-55. https://doi.org/10.1016/j.jas.2015.02.004

Ebolese, D. Lo Brutto, M. & Dardanelli, G. (2019). UAV Survey for the Archaeological Map of Lilybaeum (Marsala, Italy). *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W11*, 495–502. https://doi.org/10.5194/isprs-archives-XLII-2-W11-495-2019

Fregonese, L., Giordani, N., Adami, A., Bachinsky, G., Taffurelli, L., Rosignoli, O. & Helder, J. (2019). Physical and virtual reconstruction for an integrated archeological model: 3D print and maquette. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W15*, 481–487. https://doi.org/10.5194/isprs-archives-XLII-2-W15-481-2019

Giglio Cerniglia, R., Palazzo, P., Vecchio, P., & Canzonieri, E. (2012). Lilibeo (Marsala). Risultati della campagna 2008. In C. Ampolo (Ed.), *Sicilia occidentale. Studi, Rassegne, Ricerche*: Erice, 12-15 October 2009, II, (pp. 225-238). Pisa: Scuola Normale Superiore.

Lo Brutto, M., & Fazio, L. (2020). 3D survey for the archaeological study and virtual reconstruction of the "Sanctuary of Isis" in the ancient Lilybaeum (Italy). *Virtual Archaeology Review, 11*(22), 1-14. https://doi.org/10.4995/var.2020.11928

Kuroczyński, P. (2017). Virtual research environment for digital 3D reconstructions: standards, thresholds, and prospects. *Studies in Digital Heritage, 1*(2), 456-476. https://doi.org/10.14434/sdh.v1i2.23330

The London Charter. (2009). For the computer-based visualisation of cultural heritage. Retrieved March 15, 2021, from http://www.londoncharter.org/

The Seville Principles. (2011). International Principles of Virtual Archaeology. Retrieved March 15, 2021, from http://smartheritage.com/seville-principles/seville-principles