EUROGRAPHICS Workshop on Graphics and Cultural Heritage (2024)
M. Corsini, D. Ferdani, A. Kuijper, and H. Kutlu (Editors)

A First Digital Reconstruction of the so-Called Armor of Theoderic

F. Collina[1], F. Fabbri[2]

[1]Department of Cultural Heritage, University of Bologna, Via degli Ariani, 1, 48121 Ravenna (RA), Italy
[2]Department of Classical Philology and Italian Studies, University of Bologna, Via Zamboni, 32, 40126 Bologna (BO), Italy

Abstract

Cultural heritage is continuously subject to numerous risk factors that threaten and compromise its integrity, hence the need to activate effective risk mitigation practices. Increasingly, digital methodologies are contributing to this field, which enables the combination of operations for documentation, preservation, and enhancement of cultural heritage. The same techniques can be profitably and equally applied for now lost objects reconstruction: together with verified historical sources, using these technologies would allow the recovery of models as consistent and faithful. Based on this meta disciplinary approach between historical-philological research and digital technologies, a reconstruction project of the so-called armor of Theoderic is proposed. Different workflows and the data collected and produced will be made explicitly open, allowing cooperation processes in an Open Science perspective. This first 3D model of the so-called armor of Theoderic may be the basis for multiple possible uses to make an iconic object of great cultural significance usable again to the public and the scientific community.

CCS Concepts:
• Computing methodologies → Mesh models, Texturing, Image-based rendering, Rasterization; • Applied Computing → Archeology

1. Short Introduction

Defined as the piece of goldsmithing of the most valuable and high quality of the early Middle Ages, the so-called “Corazza di Teoderico” was occasionally found in 1854 in the city of Ravenna during some work carried out to widen the Candiano canal [Bie95]. Initially the object was considered part of a Byzantine-made breastplate [Pav]. Once the similarity of its decoration to the pincer frieze found under the dome of Theoderic’s mausoleum was recognized, the object could be imagined as belonging to a Goth of the highest lineage [Bie95]. In addition, thanks to the discovery of a comparison in the Frankish necropolis of Krefeld-Gellep [Pir64], it was possible to say that the two D-shaped, cloisonné-worked gold plates were part of a parade saddle for horses, made of wood covered with leather (Figure 1). During the night of 19-20 November, numerous fragments of the so-called armor of Theoderic were stolen from the display case of the National Museum where it was exposed [Cav11]. What is described as the most valuable and high-quality piece of early medieval goldsmithing had thus been lost forever.

Figure 1: *Two D-shaped elements of the so-called armor of Theoderic.*

2. Research question

Cultural heritage, whether tangible or intangible, is a uniquely valuable resource for every society, but increased factors, whether human or natural, threaten its integrity [DR22]. Therefore, it is necessary and essential that its accurate preservation and documentation become a priority before any damage can compromise its integrity so that it can be safeguarded and handed down to posterity [BDGV20]. But what to do if the object of cultural interest has now been lost? This is the case with the so-called armor of Theoderic. Based on the few photographic and documentary sources available, this work set out to give a digital representation of the lost "armor" on the 100th anniversary of its theft.

DOI: 10.2312/gch.20241264

The aim of this work is twofold: on the one hand, to contribute to further research on this object and cloisonné goldsmithing in general by restoring an example of undoubted importance; on the other hand, to return to the museum and to visitors an object from the collection that has now been lost, allowing it to be enhanced, exhibited and enjoyed once again. But, given the lack of the objects and the datas for the reconstruction how can we measure the accuracy and precision of the model?

3. Innovation

In the restoration field, 3D technologies have become more important with different aims: research, preservation, dissemination, and conservation-restoration [ADVVV21]. Indeed, virtual reconstructions of cultural heritage objects can be considered a powerful scientific support for archaeological research, like for history and art history studies [GS22]. With advancements in 3D data acquisition and modeling techniques, it is now possible to accurately capture, store, and share the historical memory of built heritage in a digital format, even if it is no longer accessible [AFB*23]. Faithful 3D models can be a viable solution to save and preserve their memory. When an object is lost, the types of data used for the digital reconstruction are different. The researcher relies more on secondary data, such as historical documentation. Today, digital tools allow the reconstruction of no longer visible CH based on various sources and testing various processes for manifold purposes [BDGV20].

Our work is added to several others using 3D for reconstruction or visualization proposals whose leading domain is for architectural buildings [AFFS24] [RGGCMN*19] to give a diachronic reconstruction among time of the now lost so-called armor of Theoderic. The unique application of this work lies not only in being the first modeling from 0 of an artifact worked in cloisonné (usually, these objects are scanned [ZC22] [LZSR23]) but also in being the first digital representations of the so-called armor of Theoderic.

4. Methods and Results

Once the sources useful for the digital reconstruction of the so-called armor were identified, the proper methodology was determined. Considering the pros and cons of the various possible approaches, it was decided to use two different software for the 2D realization of the decoration first and for the three-dimensional realization of the whole afterward. This choice involved using software that we already owned, which was easy to use and could produce a product with a quickly great degree of accuracy, knowing that we could run into problems with format incompatibility.

Considering the object's measurements, obtained by photographing the negative left by the object on its exhibition stand (Figure 2) and referring to measures reported by sources [Nov98], the historical photograph with the most detail available was imported to 2D AutoCAD software and scaled (Figure 1). Then, using the polyline drawing elements, the various sections or bands that made up the left D-shaped element were first drawn. One after the other, going from the simplest decoration to the most complex, various bands of the D-shaped element were inserted.

Figure 2: *Photograph of the display stand of the so-called armor where it left its negative imprint.*

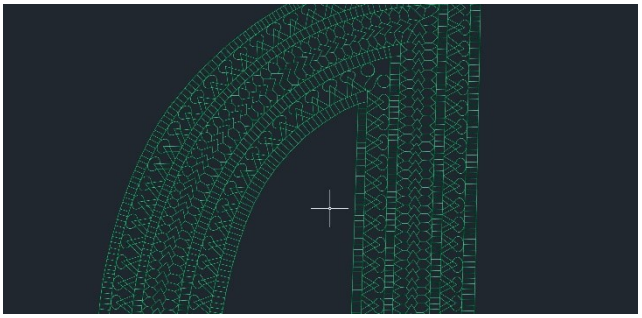

Figure 3: *The 2D decoration drawing on AutoCAD 2D.*

After an initial export test, it was clear that there were problems with the format incompatibility between AutoCAD 2D and Blender since what was displayed as arcs in the former software was then shown as a several-segment polyline in the latter. Therefore, it was necessary to replace each arc in AutoCAD with 'spline' elements or regular curves. These were then converted into polylines with such a high degree of precision that they gave the illusion of a curve. Once the problem had been solved, the first decoration to be inserted once the problem was solved was the one with rectangular alveoli, then the pincer type, and the one with bay leaf and trapezoid alveoli to conclude (Figure 3). Where possible, the elements were copied and pasted several times, thus saving time, and then re-adapted to the decorations reported in the photograph. Otherwise, the decorations were done individually, as in the case of the more complex laurel leaf and trapezium decorations.

The left D-element completed was then mirrored to obtain the right one by making changes to make it match the photograph. Finally, to realize two closed surfaces that could be used for making the bases in Blender, the polylines that bounded the two D-elements were extrapolated. Once finished, these elements were exported in .dxf format. The whole thing was imported to Blender, scaled, and transformed into a mesh (the imported elements were seen by Blender as curves). The decorated elements and the bases were extruded by 0,2 (plus 0,1 cm for the central decoration) and

Figure 4: *A first 3D model of the D-shaped elements of the so-called armor, relocated to the exhibition stand.*

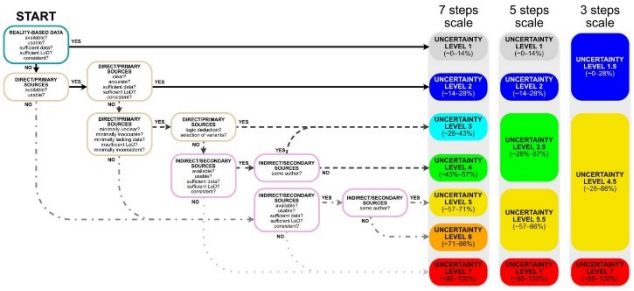

Figure 5: *Yes/no flow chart that aids the use of the updated scale of uncertainty [AFFS24].*

0,1 cm on the Z-axis, respectively, according to sources [Nov98]. Using Blender's "Solidify" modifier, a thickness was assigned to the decorated elements based on the photograph (about 0,02 cm). Referring to a second historical photograph, we proceeded to detail the backs of the Ds characterized by the presence of pegs and light grooves. Elements were then created with a square section of side 0,5 mm that had the same shape as represented in the grooves, and that would fit into the base just enough to create precisely visible grooves once subtracted from its surface using the "Boolean" modifier. After that, pegs were created and placed according to the photograph on both bases of the D-elements.

The last step involved the application of texture. Seeing the refractive index of gold (0,47) and referring to the appearance of the few surviving fragments, using a series of Shader Nodes, it was possible to recreate a plausible material to which it was assigned some degree of "degradation" to make it look ancient. Finally, a light source was added to the model to illuminate it and allow the details of the decoration to be grasped. From our HD photograph, we set out to reconstruct the armor's display stand. According to the photo, we modeled the stand in all its shapes and sizes. We assigned a wood-like texture to the frame and then applied the texture obtained from the photograph to the velvet part of the stand. Lastly, the D-elements were placed back on their display stand. The D-elements were then virtually relocated, 100 years later, to their exhibition stand (Figure 4).

Given the lack of methodologies to measure the percentage of uncertainty in the user-generated reconstruction of objects of small scale, we referred to the methodology that Apollonio applied for architecture reconstructions [AFFS24]. Based on two indicators (geometry and surface), a yes/no chart was used to evaluate the level of accuracy and understand the gaps in the sources to lower the level of uncertainty (Figure 5). One of the first purposes that the reconstruction of the so-called armor could take on is to give a boost to research in the field of cloisonné goldsmithing, allowing experts to analyze no longer just photographic images but to finally be able to touch a three-dimensional object with their own hands. For this, the desire is to publish all the data collected and generated in Open Access, according to the principles of Open Science, so that research results can be disseminated and shared without barriers or restrictions and thus create a circle of information that could bring new data helpful for improving the model.

Finally, one of the future steps, counting improving the 3D model, could be to virtually enhance the so-called armor through WebGL technology. This will be embedded within an open-source framework for creating mixed reality developed by the CNR called ATON; then, enhancements, such as annotations addition, will be applied to make the model interactive and informative. Users who enjoy it will thus be able to explore the elements in real-time and interact with them through different tools such as lights, annotations, and measurements [FFD*21]. This digital interaction by visitors to the National Museum of Ravenna would allow them a larger understanding of the now-lost object. Furthermore, the interactivity of the model will allow for better involvement on the part of the public, who will be encouraged to handle the object and thus understand it.

References

[ADVVV21] ACKE L., DE VIS K., VERWULGEN S., VERLINDEN J.: Survey and literature study to provide insights on the application of 3D technologies in objects conservation and restoration. *Journal of Cultural Heritage 49* (5 2021), 272–288. doi:10.1016/j.culher.2020.12.003. 2

[AFB*23] ALKHATIB Y., FORTE A., BITELLI G., PIERDICCA R., MALINVERNI E.: *Bringing Back Lost Heritage into Life by 3D Reconstruction in Metaverse and Virtual Environments: The Case Study of Palmyra, Syria*, vol. 14219 of *Lecture Notes in Computer Science. Springer*. Springer Nature Switzerland, Cham, 2023, pp. 91–106. doi:10.1007/978-3-031-43404-4_7. 2

[AFFS24] APOLLONIO F. I., FALLAVOLLITA F., FOSCHI R., SMURRA R.: Multi-Feature Uncertainty Analysis for Urban-Scale Hypothetical 3D Reconstructions: Piazza delle Erbe Case Study. *Heritage 7*, 1 (Jan. 2024), 476–498. doi:10.3390/heritage7010023. 2, 3

[BDGV20] BALLETTI C., DABROWSKI M., GUERRA F., VERNIER P.: Digital reconstruction of a lost heritage: the San Geminiano's church in San Marco's Square in Venice. pp. 304 – 310. URL: https://www.imeko.org/publications/tc4-Archaeo-2020/IMEKO-TC4-MetroArchaeo2020-057.pdf. 1, 2

[Bie95] BIERBRAUER V.: *Archeologia degli Ostrogoti in Italia*. San Marino; Milano, 1995, pp. 34–47. 1

[Cav11] CAVANI F.: La cosiddetta Corazza di Teoderico: discussioni. *Orizzonti: rassegna di archeologia XII* (2011), 143–164. 1

[DR22] DANESH M. M., RAJABI A.: *Importance of Digital Techniques*

of Documentation for the Conservation of Cultural Heritage. Springer, Cham, 2022, pp. 415–425. doi:10.1007/978-3-030-744823_32. 1

[FFD*21] FANINI B., FERDANI D., DEMETRESCU E., BERTO S., D'ANNIBALE E.: ATON: An Open-Source Framework for Creating Immersive, Collaborative and Liquid Web-Apps for Cultural Heritage. *Applied Sciences 11*, 22 (11 2021), 11062. doi:10.3390/app112211062. 3

[GS22] GHERARDINI F., SIROCCHI S.: Systematic integration of 2D and 3D sources for the virtual reconstruction of lost heritage artefacts: the equestrian monument of Francesco III d'Este (1774–1796, Modena, Italy). *Heritage Science 10*, 1 (6 2022), 96. doi:10.1186/s40494-022-00711-8. 2

[LW21] LANJOUW T., WAAGEN J.: 4DRL Report Series 1 - Making 4D: principles and standards for virtual reconstruction in the humanities by the 4D Research Lab. *Journal contribution* (2021). doi:10.21942/uva.14932461.v3. 1

[LZSR23] LIU B., ZHANG F., SUN X., RUSHWORTH A.: *Additive Manufacturing in Cultural Heritage Preservation and Product Design*. Springer International Publishing, 2023, pp. 923–940. doi:10.1007/978-3-031-20752-5_55. 2

[Nov98] NOVARA P.: Storia delle scoperte archeologiche di Ravenna e classe. I secoli XV – XIX. *Danilo Montanari Editore* (1998). 2, 3

[Pav] PAVIRANI P.: Scoperta di un antico sepolcreto in Ravenna. *Biblioteca Classense di Ravenna*. Mob. 3.2. 1

[Pir64] PIRLING R.: Ein fränkisches Fürstengrab aus Krefeld-Gellep. *Germania 42* (1964), 188–216. 1

[RGGCMN*19] RODRÍGUEZ-GONZÁLVEZ P., GUERRA CAMPO A., MUÑOZ-NIETO A., SÁNCHEZ-APARICIO L., GONZÁLEZ-AGUILERA D.: Diachronic Reconstruction and Visualization of Lost Cultural Heritage Sites. *ISPRS International Journal of Geo-Information 8*, 2 (2 2019), 61. doi:10.3390/ijgi8020061. 2

[ZC22] ZHAO M., CUI J.: *Artificial Intelligence Boosting Protection and Communication of Intangible Cultural Heritage*, vol. 7. Atlantis Press International BV, 12 2022, pp. 1126–1133. doi:10.2991/978-94-6463-010-7_115. 2