Digitalising antiquity:
the example of terracotta figurines in Ancient Egyptian collections

Alessandro Mandelli & Clementina Caputo

Abstract

The production of terracotta figurines as an art form is germane to a number of ancient civilizations and it carries undoubtedly a certain social value. Although their production represented a major activity during antiquity, they have been often qualified as a 'minor' production, being a mass-produced item made from a low-cost material. In the study of ancient terracotta figurines, the rewards are greatest when examining the broadest possible spectrum of production, rather than focusing on one individual figurine. One of the main sources to study these artefacts is represented by museum collections. The projects *SUR.VI.V.E. (SURveying VIrtual Voids in Egyptian collections). A Digital and Cultural Study on Terracotta Figurines and their Lost Molds* and its extension with *SUR.VI.V.E.-Phase 2* stem from the idea of combining the analytical approaches used so far in the study of the terracotta figurines with the innovative digital methodologies. The methodology developed during the first phase of the project and focused on the corpus of ancient Egyptian terracotta figurines kept in the collection of the *Museo Egizio* in Turin, will be applied in the next three years to other groups of objects that, differently from the collection of *Museo Egizio*, will be selected according to different and more specific criteria, like the degree of their preservation and provenance. The application of digital techniques and virtual 3D rendering in a more systematic way on different clusters of materials will facilitate the knowledge and the access to surveyed terracotta figurines, even those preserved in 'minor' collections, in order to implement the comparative study of this category of objects. The methodology applied in the project has the advantage of using non-invasive and replicable techniques, as well as the possibility of spreading the results both to academia and to the general public. It was designed with a triple aim in mind: to be proportional to the available data, to be universally replicable, and to function as repository of information. 3D models may be used for dissemination purposes, but their final aim is to be used for current and future research purposes.

Keywords: *Material culture; Egyptian Collections; Terracotta figurines; Popular cult; 3D modelling.*

1. Introduction (AM, CC)

In the last decade, 3D technologies have become increasingly prevalent in archaeology and cultural heritage, offering numerous applications both in the field and in research labs. Especially, 3D modelling is transforming these research fields, providing a more detailed and accurate representation of artefacts compared to traditional 2D images like photographs and drawings. High-quality 3D models allow researchers to access more precise data and to share these models widely, fostering greater collaboration within the academic community. Applying digital techniques and virtual 3D rendering to different museum collections will also facilitate the study of several categories of objects, including those in less prominent collections, enabling more comprehensive comparative research.

The integration of traditional analytical approaches with innovative digital methodologies represented the foundation of the Project *SUR.VI.V.E. (SURveying VIrtual Voids in Egyptian collections) A Digital and Cultural Study on Terracotta Figurines and their*

Lost Molds and its extension *SUR.VI.V.E.-Phase 2* at Politecnico di Milano.[1] The aim of the project was to systematically apply digital techniques to the corpora of ancient Egyptian terracotta figurines from a museum collection (Fig. 1), in our specific case those of Museo Egizio in Turin, and to explore how 3D models can be applied to a category of artifacts in order to enhance our understanding of their material aspects. This approach could serve as a model for future research in coroplastic studies, inspiring renewed academic interest in the field.

Fig. 1: Display cases of the collection containing the terracotta figurines. *Museo Egizio, Torino* © Caputo.

The production of terracotta figurines was common across many ancient civilizations and held social significance, as reflected in their role in creation myths. Despite their humble nature, terracotta figurines survived better than many more luxurious items, providing a rich and diverse glimpse into religious beliefs, divine representations, and social ideologies. Although terracotta figurines were often dismissed as 'minor' art due to the cheap material and mass-production methods, their frequent appearance and the large-scale production suggest they played a significant role in ancient life. As such, their study is essential to gain a deeper understanding of past civilizations, particularly the non-elite populations. To obtain the most from studying ancient terracotta figurines, it is crucial to look at a wide range of production rather than focusing on individual pieces, for this reason museums are one of the primary resources for studying them.

The following paragraphs will focus on the significance of 3D surveying, the technologies involved, and the various applications of 3D modelling in the various research fields, as well as within the Project *SUR.VI.V.E.* However, only a small portion

[1] The Project *SUR.VI.V.E.*, conducted under the supervision of Corinna Rossi (DABC-Politecnico di Milano), is funded by the Politecnico di Milano and awarded of the "Seal of Excellence" by the European Commission (H2020-MSCA-IF-2019).

of the collections is usually on display, chosen for their aesthetic appeal, iconography, or known provenance. It is likely that many specimens remain unpublished and unknown to both experts and general public. Given that these objects were produced in large quantities, often in series, and are not always fully preserved, this is understandable. Even when published, they have typically been treated as art objects rather than artefacts related to everyday life, often selected for their completeness and described primarily from an iconographic or artistic perspective. However, since the late 20th century, traditional catalogues that focus solely on descriptive, iconographic, and art-historical aspects are being replaced by more advanced studies. These newer approaches examine the material characteristics, production techniques, and sociocultural contexts of terracotta figurines. This shift has been driven by a growing interest in reconstructing the material culture of ancient societies and by comparing artifacts from well-documented archaeological contexts using modern scientific methods.

2. 3D surveying and modelling technologies (AM)

In recent years, 3D surveying and modelling have become pivotal tools in various branches, revolutionizing the way we approach design, analysis, and reproduction of physical objects. The integration of 3D surveying with advanced modelling techniques allows for the accurate digitization of real-world objects, enabling their manipulation, analysis, and reproduction with unprecedented precision.

More specifically, 3D surveying is the process of capturing the physical shape and appearance of an object using specialized hardware and software to create a digital representation. This digital model can then be used in various applications, such as reverse engineering, quality control, and digital archiving. The data collected by 3D sensors is typically a set of points in space, known as a point cloud, or a continuous surface, known as a mesh, which represents the exterior of an object.[2]

2.1 Sensors

There are several types of 3D sensors, both cameras and scanners, each using different principles and technologies to capture data. In the first case, the technique related to the use of cameras is called photogrammetry, while in the other cases we speak of 3D scanning. Photogrammetry and 3D scanning are powerful techniques used to create three-dimensional models of real-world objects and environments. Both methods have applications in a wide range of fields, from archaeology and architecture to gaming and virtual reality. Understanding the differences between photogrammetry and 3D scanning, particularly in the context of active and passive sensors, is crucial for selecting the right technology for a specific task. Both methods have their strengths and weaknesses, which are influenced by the types of sensors they use. Sensors are integral components of both photogrammetry and 3D scanning systems. They can be broadly classified into two categories: active and passive sensors. The primary distinction between these types lies in how they acquire information about the environment.

---

[2] Remondino 2011, 1104-1138.

2.2 Active sensors

Active sensors emit their energy (such as light, laser, or sound) and measure the response to gather information about the environment. This type of sensor is commonly found in many 3D scanning systems. Active sensors are independent from ambient light, namely they do not rely on external light sources, making them effective in various lighting conditions, including complete darkness. Moreover, they can provide highly accurate measurements, particularly over short to medium distances and can capture detailed information from complex surfaces, including those with varying textures and colours.[3]

3D scanners can quickly capture the geometry of an object, making them suitable for time-sensitive applications. These sensors have a few disadvantages, in fact: i) they generally require significant power to operate due to the need to emit energy, which can be a limitation in portable or battery-operated devices; ii) the technology behind active sensors can be expensive, particularly for high-end systems like LiDAR; iii) they can be susceptible to interference from other sources of the same energy, such as other lasers or bright lights in the environment; iv) some 3D scanners have difficulty capturing shiny, transparent, or reflective surfaces; v) the use of 3D scanners often requires specialized knowledge and training. There are two main families of 3D scanners: Time-of-Flight (ToF) scanners that emit laser pulses and measure the time it takes for the pulses to return after hitting an object; and structured-light scanners that project a pattern of light (usually stripes) onto an object and use cameras to capture the deformation of the pattern, which is then used to calculate the 3D shape.[4]

2.3 Passive sensors

Passive sensors, on the other hand, do not emit their energy, they detect natural energy that is either emitted or reflected by objects in the environment. Digital, thermal, multispectral and hyperspectral cameras are some examples of passive sensors. Digital cameras capture reflected light from objects. They are the primary tool used in photogrammetry; thermal cameras detect infrared radiation emitted by objects, allowing them to capture images based on temperature differences; multispectral and hyperspectral cameras capture data across multiple wavelengths of light, providing detailed information about the composition of objects. Photogrammetry is a technique that reconstructs 3D models from 2D images. It relies on the principles of geometry, specifically triangulation, to calculate the positions of points in space based on images taken from different angles. Photogrammetry involves capturing multiple overlapping images of an object or scene from various viewpoints. These images are then processed using specialized software that identifies common points in the images and calculates their 3D coordinates. The software uses algorithms to match points across the images, essentially "stitching" them together to a coherent 3D model. The final 3D model is directly related to the resolution of the images captured and the precision of the camera calibration process; photogrammetry is also very versatile, in fact, the same camera can be used to survey a wide range of objects and environments, from small artefacts to

---

[3] Ramos 2015, 359-363.
[4] Guidi 2015, 321-324.

large landscapes, or indoor scenes. Compared to 3D scanners, digital cameras have some advantages, such as a limited power consumption since they do not emit energy and usually they are less expensive than active sensors. On the contrary, passive sensors are less effective in low light conditions since they rely on external light sources or emitted energy; regarding the data elaboration, the process of matching points and generating 3D models can be computationally intensive and time consuming particularly for large datasets. This makes 3D scanning more efficient for projects with tight deadlines or when large areas need to be scanned.[5]

Photogrammetry and 3D scanning are both powerful techniques for creating 3D models, each with its advantages and limitations. Photogrammetry is a cost-effective and versatile method that excels in applications where high-resolution images and large-scale models are needed. However, it is limited by lighting conditions and may not achieve the same level of precision as 3D scanning.

On the other hand, 3D scanning, particularly with active sensors, offers high precision and speed, making it ideal for applications where accuracy is critical. However, the cost and complexity of 3D scanning technology can represent a barrier to entry for some users.[6]

The choice between photogrammetry and 3D scanning ultimately depends on the specific requirements of the project, including the desired level of accuracy, budget, and environmental conditions.[7] Understanding the differences between active and passive sensors is also crucial, as it informs the selection of the appropriate technology for capturing the necessary data. Whether preserving cultural heritage, designing buildings, or ensuring product quality, both photogrammetry and 3D scanning offer valuable tools for capturing and analysing the physical world.[8]

2.4 Application fields

3D surveying and modelling have a wide range of applications across various industries, such as manufacturing and engineering, healthcare, entertainment and gaming, architecture and construction, art and design and cultural heritage. In manufacturing, 3D surveying is often used for quality control and reverse engineering. By scanning a finished product, manufacturers can compare it to the original design to ensure it meets specifications. Reverse engineering involves scanning a physical object to create a digital model, which can then be used to produce a new version of the object.

In healthcare, 3D surveying helps in creating custom prosthetics and orthotics. By scanning a patient’s body, medical professionals can design devices that fit perfectly, improving comfort and effectiveness. 3D models are also used in surgical planning, allowing doctors to visualize and plan complex procedures.

In the entertainment industry, 3D surveying is used to create realistic characters and environments. Actors can be scanned to create digital doubles, and real-world locations can be digitized for use in movies and video games. This technology allows for more immersive experiences and faster production times.

---

[5] Agapiou 2023.
[6] Baltsavias 1999.
[7] Melendreras Ruiz 2021.
[8] Remondino, Campana 2014; Styliandis, Remondino 2016.

Architects and construction professionals take advantage of 3D surveying to capture the details of existing structures. This information can be used to create accurate models for renovation or restoration projects, ensuring that new work integrates seamlessly with the old. Scanning can also be used to monitor the progress of construction projects, ensuring that everything is built according to plan.

Artists and designers use 3D surveying to digitize their work or to create new forms of art. By scanning a physical object, they can manipulate it in digital space, experimenting with new ideas and creating complex designs that would be difficult or impossible to achieve by hand.

In museums and cultural institutions 3D surveying facilitates conservation and documentation of artefacts. By creating digital replicas of objects, they can be studied, shared, and even reproduced without risking damage to the original items. This technology also enables virtual tours, allowing people to explore cultural heritage sites from anywhere in the world.[9]

3. The role of 3D scanning in Cultural Heritage preservation (AM)

3D surveying has emerged as a ground-breaking technology in the field of cultural heritage preservation. It provides a non-invasive, highly accurate method of documenting and analysing cultural artefacts, monuments, and historical sites. This technology has revolutionized the way we approach the conservation and restoration of our shared cultural heritage, offering numerous benefits that were previously unimaginable. One of the primary advantages of 3D surveying in cultural heritage is its ability to capture detailed and precise measurements of objects and sites. Traditional methods of documentation, such as photography or manual measurement, often fall short in capturing the intricate details of ancient sculptures, buildings, or artefacts. 3D surveying, on the other hand, can create accurate digital replicas with sub-millimetric precision. These digital models can be used for a variety of purposes, including research, conservation, and public education. Moreover, 3D models allow for the creation of digital archives of cultural heritage objects. These archives serve as a valuable resource for researchers and historians, enabling them to study artefacts that may be in distant or inaccessible locations. In cases where physical objects are at risk of degradation due to environmental factors or human activity, digital preservation ensures that a detailed record is maintained, potentially aiding in future restoration efforts.[10]

Another significant benefit of 3D models is its role in restoration and reconstruction projects. Digital models created through 3D surveying can be used to design and test restoration techniques in a virtual environment before applying them to the actual object. This minimizes the risk of further damage and allows conservators to experiment with different approaches. Additionally, 3D printing technology, which is often used in conjunction with scanning, can produce physical replicas of lost or damaged parts of cultural heritage objects, facilitating their restoration. Furthermore, 3D models enhance public engagement with cultural heritage. Digital models can be used to create virtual reality experiences, allowing people to explore historical sites or artefacts from anywhere in

[9] https://www.cyark.org/projects/

[10] Morgan 2022, 213-225.

the world. This democratizes access to cultural heritage, making it possible for individuals who may never have the opportunity to visit these sites in person to experience and learn about them. 3D models offer precise documentation, support conservation efforts, aid in restoration, and expand public access to cultural heritage. As the technology continues to advance, their role in preserving our shared history will only become more vital.

4. **Studying the corpus of Egyptian terracotta figurines (CC)**

Egyptian craftsmen used moulds to produce terracotta figurines since as early as the New Kingdom.[11] However, some technological practices, such as the use of multiple moulds to cast hollow clay figurines, were first developed in the Greek world before reaching Egypt.[12] These developments highlight the interaction between Greek and Egyptian artistic traditions and how new methods were adapted to create objects for traditional religious purposes.

The study of terracotta figurines poses to the researcher specific problems that require a different approach compared to other forms of ancient sculpture, such as understanding the role of coroplasts, their individual role as artisans and their integration in a wider social sphere as artists. This includes investigating how knowledge and techniques were passed down through generations, the influence of local and external factors, and how the preferences of buyers shaped the production. Often mass-produced, these figurines provide insights into the decisions of the artisans, the economic conditions and the market for these items. The study of terracotta figurines also involves examining the methods used to create them, such as hand modelling or the use of moulds, as well as the various decorative techniques that were employed.[13] These methods were designed for efficient production, as coroplasts prioritized quantity over creating unique masterpieces. Nonetheless, mass-produced items often feature individual craftsmanship, such as small details added by means of tools or directly by hand.

The analysis of the clay fabrics used to make the products, the style, and the direct comparison with similar pieces from recent excavations can certainly help us to define whether they belong to a specific geographical context. However, determining the origin and dating of terracotta figurines preserved in museum collections can be difficult. Indeed, much of the material in modern museum collections was acquired through antiquities trade or poorly documented excavations from the late 19th century. As a result, precise find-spots and contexts for many figurines are unknown, making it challenging to fully understand their historical and cultural significance.

Recent technological advancements, including 3D modelling and digital analysis, offer new ways to study these figurines. These tools allow researchers to virtually reconstruct missing parts, trace production techniques, and even identify the original moulds used. An example is the *SUR.VI.V.E.* project at Politecnico di Milano, which applies these methods to a collection of 542 terracotta figurines kept in the Museo Egizio and found during the excavations carried out in the early 1900s by Italian scholars and researchers

[11] On the techniques applied to the partially moulded pottery figure vases of the New Kingdom, see Bourriau 1987, 81-96; Dormann 2002.
[12] Barrett 2011, 91 and fn. 277-278, and 99, fn. 307, with further references. See also Caubert *et al.* 1998; Blondé, Muller 2000.
[13] Ballet 1997, 207-213; Ballet 2020, 46-49; Caputo, Mandelli 2023.

in various Egyptian sites.[14] One of the main objectives of the project *SUR.VI.V.E.* was to provide a first systematic and in-depth digital study of a collection of terracotta figurines and to single out criteria replicable in other collections.

5. Surveying the corpus of Egyptian terracotta figurines (AM, CC)

As anticipated in the previous paragraphs, both scanners and cameras could be used to digitalise the corpus of terracotta figurines as the results are comparable in terms of precision and resolution. Regarding the texture it is undeniable that the photogrammetric texture is way better than the texture acquired by the scanner.

The *SUR.VI.V.E.* project considered the use of a structured light scanner, namely the ARTEC EVA,[15] since the large number of figurines and the poor texture that characterises these kind of objects. The scanner is coupled with its proprietary software, ARTEC STUDIO v.17, that follows the operator during the whole process, from the acquisition to the final model. This scanner model is the best choice for medium sized objects ranging from some centimetres up to a couple of meters. The acquisition phase is undoubtedly fast, in a single day it was possible to record up to 20 statuettes, acquiring an average of 5 scans for each object; the operator moves smoothly around the object checking in real time on the laptop screen the alignment of the frames (Fig. 2). This feature helps the surveyor understanding if some parts of the objects are missing, in this case it is possible to improve the survey completing the model.

Fig. 2: Digitalization of a terracotta figurine. *Museo Egizio, Torino* © SUR.VI.V.E.

[14] For the history of the excavations, see Moiso 2008, 199-269; Del Vesco, Moiso 2017. See also Caputo, Mandelli 2023, 79-95.
[15] Kęsik 2023; Muminović 2024.

Once the acquisition is completed, the raw data are stored on the hard drive and the elaboration can then be performed at any time, thus allowing to digitise all the objects in a row reducing the time objects are not on display in the museum. Each figurine was digitised setting the acquisition parameters to the maximum value, i.e. accuracy up to 0.1 mm and resolution equal to 0.2 mm. The subsequent elaboration process starts with the alignment of the scans: this step is performed automatically by the software using the ICP (Iterative Closest Point) algorithm, if it fails it is possible to proceed manually. Before proceeding to the subsequent processing phases, it was verified that the overall deviation between scans never exceeded the limit of 0.5 mm. The following step is cleaning the scans to remove unwanted objects, such as the supporting structures of the figurines. Then the data are ready to be converted in a continuous 3D surface that is called mesh. It was decided to apply the sharp fusion to build the mesh since this option is capable to perfectly reconstructs fine features and is suited to both industrial objects and human bodies. The final resolution of the mesh is close to 0.5 mm. The goal is to obtain a regular smooth and sealed 3D geometry so that each photo captured by the camera scanner could be re-projected on the surface. If the mesh respects these characteristics, the area, the volume and consequently the weight could be computed.

6. Deliverables (AM)

The models obtained at the end of the surveying and modelling stages are the digital replicas of the entire corpus. These models are accurate from a metric point of view, and they preserve also the colorimetric information. Once the 3D models are exported in various file formats, such as .obj and .stl, they can be used for several purposes, from detailed digital databases and museum collections to 3D printing and virtual and augmented reality. The digitisation of cultural heritage is making artefacts more accessible and interactive than ever before.[16]

6.1 Databases and digital archives

One of the most direct applications of 3D models of cultural heritage artefacts is their incorporation into databases and digital archives. Traditionally, museums and cultural institutions have stored information about their collections in textual or photographic formats. However, 3D modelling offers a more comprehensive and dynamic means of documenting artefacts.[17] A 3D model can capture the object from all angles, allowing for detailed analysis of its shape, texture, and physical features that 2D images cannot replicate. The databases provide accessibility for researchers, scholars and archaeologists can access 3D models of artefacts without having to physically visit the institution where the object is housed. This global accessibility facilitates collaboration between experts across different countries and disciplines. For example, an archaeologist in Germany can study a digital model of an artefact located in a museum in Egypt, using the detailed 3D renderings to conduct analysis or comparisons with local findings. Databases ensure detailed preservation of objects, artefacts, particularly those made from fragile materials such as paper, wood, or textiles, are prone to deterioration over time. 3D models serve

[16] Huggett 2022, 275-304.
[17] Ioannides *et al.* 2018.

as a detailed record of an object's condition at a given point in time, preserving its form digitally even if the original item is later damaged or lost. Moreover, 3D models offer museums and cultural institutions a powerful tool for cataloguing and managing their collections. Detailed 3D scans can be used to create virtual catalogues, which make it easier for curators to keep track of objects, assess their condition, and plan conservation strategies.

6.2 Virtual museum's collections and online exhibitions

Incorporating 3D models into virtual museum collections and online exhibitions is another growing use of this technology. Many museums and heritage institutions have turned to digital platforms to make their collections more widely accessible to the public. This shift was particularly accelerated by the COVID-19 pandemic, which forced institutions worldwide to close their physical doors temporarily. 3D models enhance online exhibitions by offering a more interactive and immersive experience. Visitors to virtual museum websites can explore detailed, photorealistic models of artefacts, rotating them, zooming in to examine fine details, and sometimes even interacting with the objects in ways that would be impossible in a physical museum setting. 3D models enhance the engagement and interactivity with the objects, online visitors can interact with artefacts in ways that go beyond simply viewing a photograph. By allowing users to manipulate 3D models, museums can create more engaging experiences that promote curiosity and deeper learning. For instance, virtual exhibitions may let users "handle" delicate objects like ancient pottery, turning them around and zooming in to see tiny inscriptions or decorative details that would be difficult to observe even in person. Digital collections allow museums to reach a far broader audience than ever before. People who cannot visit the physical museum, whether due to geographic, financial, or physical barriers, can still access the collection online. Furthermore, 3D models are excellent tools for education purposes: history or archaeology classes can use 3D models to study artefacts from ancient civilizations, enhancing the learning experience with immersive and interactive content.

6.3 3D printing and artefact replication

3D printing is another application of 3D modelling technology in the field of cultural heritage. High-resolution 3D scans of artifacts can be used to create accurate physical replicas, which can serve a variety of purposes, from educational tools to conservation aids. Replica artifacts can be used in classrooms and museums to provide a hands-on learning experience. Handling a replica object can offer insights that viewing a photograph or video simply cannot provide. For example, students studying ancient tools or pottery can better understand how these objects were used by physically interacting with a 3D-printed replica. 3D printing can also aid in the conservation of fragile or incomplete artifacts. If an artifact is missing a piece, a 3D scan of the object can be used to create a replica of the missing part, which can then be attached to the original artifact to restore it to its former state. This approach is particularly useful in archaeology, where incomplete artifacts are common. By digitally reconstructing missing elements, conservators can restore the artifact in a non-invasive way, preserving its integrity while also making it more comprehensible to the public. 3D replicas allow museum deciding how to display delicate or valuable artifacts. Original pieces may be too fragile for permanent display, or there may be security concerns regarding theft or damage. In such cases, 3D-printed replicas can be used in place of the original objects, allowing visitors to view and even handle the replicas without risking the safety of the original artifact.

6.4 Virtual and augmented reality (VR/AR)

Virtual and augmented reality offer some of the most innovative and immersive uses of 3D models of cultural heritage artifacts. These technologies have the potential to transform how people experience and interact with history. VR allows users to enter fully immersive digital environments, where they can explore cultural heritage sites or handle artifacts in ways that would be impossible in real life. For example, a VR experience might transport users to ancient cities, allowing them to walk through its streets, enter their buildings, and examine artifacts in situ. VR can also recreate the original contexts of artifacts, showing them as they would have appeared in their historical environments. A VR simulation of an ancient tomb might show visitors the objects in the positions where they were originally placed by the tomb's occupants. AR offers a different kind of experience, blending the physical and digital worlds. In a museum setting, visitors can use AR devices (such as smartphones or AR glasses) to enhance their experience by viewing additional information or digital reconstructions overlaid onto physical objects.[18] For instance, an AR app might allow visitors to point their phones at an ancient vase and see it reconstructed to its original, complete form, or display information about its historical context. These technologies permit to develop remote virtual tours allowing users to "visit" a museum or archaeological site from their own home. These experiences can be highly interactive, allowing users to move through space, examine 3D models of artifacts, and even interact with digital reconstructions of historical figures or environments. 3D modelling, VR, and AR offer ways to digitally reconstruct important cultural heritage sites that have been lost or damaged due to war, natural disasters, or urban development, preserving their memory for future generations.[19]

6.5 Archaeological documentation and analysis

3D modelling is an invaluable tool in archaeological documentation and analysis. Traditional methods of recording archaeological finds, such as sketches or photographs, can be imprecise or incomplete. 3D scanning allows for highly accurate digital documentation of artifacts and excavation sites. Archaeologists can use 3D scanning to document excavation sites in three dimensions, capturing not only the artifacts themselves, but also their spatial relationships to one another. This detailed documentation can be used for later analysis, allowing researchers to revisit the site digitally long after the excavation has been completed, moreover if the 3D surveying is performed at different time thresholds it is possible to go back in time and explore the evolution of the excavation. 3D modelling can assist the reconstruction of fragmented artifacts manipulating and fitting them together in ways that are much more difficult to

[18] Liritzis *et al.* 2021.
[19] Addison 2000, 26-31.

achieve using physical pieces alone. This digital reconstruction can serve as a guide for conservators as they restore the original artifact (Fig. 3).

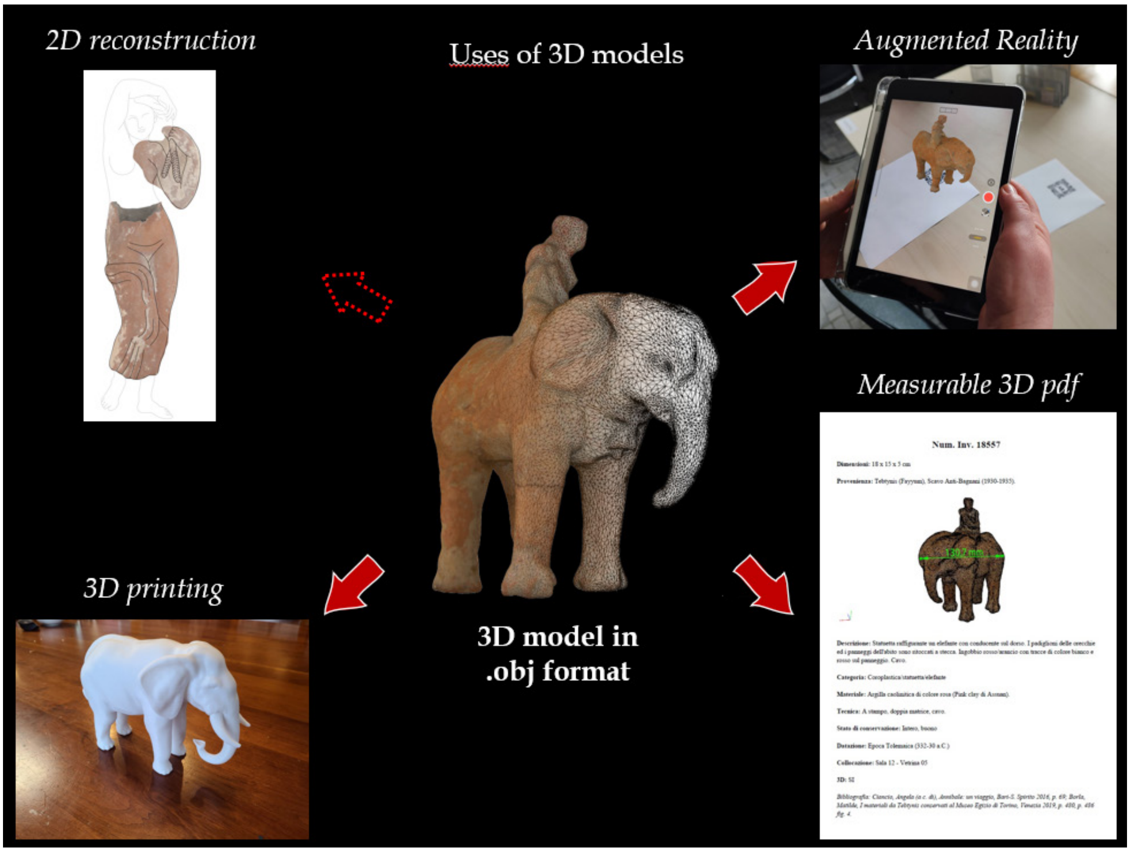

Fig. 3: Some examples of deliverables using a model of the digitized collection. *ABCLab-Eidolon, Politecnico, Milano* © SUR.VI.V.E.

7. Final remarks

In conclusion, the uses of 3D models of cultural heritage artefacts are varied and transformative, ranging from digital preservation and interactive museum collections to educational tools, archaeological documentation, and immersive VR and AR experiences. These technologies are not only preserving our past but are also making it more accessible, engaging, and interactive for people across the world. By leveraging these advances, we can ensure that future generations continue to learn from and appreciate the rich cultural heritage that defines human history.[20]

As technology continues to advance, 3D surveying and modelling are likely to become even more integral to various fields. The increasing accuracy and affordability of 3D sensors are making this technology accessible to more people and industries. In the future, we can expect to see even more sophisticated applications, such as real-time 3D capturing, which would allow for instant digitization of objects and environments. Additionally, the

[20] Dell'Unto, 2014.

integration of 3D surveying with artificial intelligence and machine learning could lead to new ways of analysing and interacting with digital models. For example, AI could be used to automatically identify and classify objects in an environment or to suggest design improvements based on surveyed data[21]. 3D surveying and modelling are powerful tools that have transformed the way we interact with the physical world. From manufacturing to medicine, these technologies are enabling new levels of precision, efficiency, and creativity. As they continue to evolve, they will undoubtedly play an increasingly important role in shaping the future of technology and design.

Acknowledgements

The Authors would like to thank the Organizing Committee of the International Conference ANCIENT Egypt NEW Technology, Stefania Mainieri, Maria Diletta Pubblico, Ilaria Incordino, Carlo Rindi Nuzzolo and Anna Clelia Salsano, for inviting us to prepare this paper and share the preliminary results of the Project *SUR.VI.V.E. Phases 1-2* in this volume. Special thanks go to the Director Christian Greco and to the entire staff of the Museo Egizio, all curators and registrars, for the constant support and collaboration in carrying out the various phases of the project. Finally thanks also to Corinna Rossi (DABC-Politecnico di Milano) for her valuable advice for the implementation of the project and the present contribution.

References

A.C. Addison, M. Gaiani, 2000. Virtualized architectural heritage: new tools and techniques, in *IEEE MultiMedia*, vol. 7, issue 2 (April-June 2000), 26-31 [https://ieeexplore.ieee.org/document/848422, accessed October, 2025].

A. Agapiou, D. Skarlatos, 2023. *Geomatic Sensors for Heritage Documentation: A Meta-Analysis of the Scientific Literature*. Heritage, 6(10), 6843-6861, [https://doi.org/10.3390/heritage6100357, accessed October, 2025].

P. Ballet, 1997. Le moulage des terres cuites dans l'Égypte gréco-romaine: état des problématiques, in A. Muller (ed.), *Le moulage en terre cuites dans l'Antiquité. Création et production dérivée. Fabrication et diffusion. Actes du XVIIIe Colloque du Centre de Recherches Archéologiques, Lille III (7–8 décembre 1995)*, Collection UL3. Travaux et recherches, 207-213. Lille.

P. Ballet, 2020. *Figurines et société de l'Égypte ptolémaïque et romaine*. Paris.

E.P. Baltsavias, 1999. A comparison between photogrammetry and laser scanning, *ISPRS Journal of Photogrammetry and Remote Sensing*, Volume 54, 2–3, 83-94, ISSN 0924-2716 [https://doi.org/10.1016/S0924-2716(99)00014-3, accessed October, 2025].

C.E. Barrett, 2011. *Egyptianizing Figurines from Delos. A Study in Hellenistic Religion*, Columbia Studies in Classical Tradition 36. Leiden-Boston.

F. Blonde, A. Muller (eds.), 2000. *L'artisanat en Grèce ancienne. Les productions, les diffusions, Actes du Colloque de Lyon (10-11 décembre 1998) organisé par l'École française d'Athènes, la Maison de l'Orient méditerranéen Jean Pouilloux et l'Université Charles-de Gaulle*, Collection UL3. Lille.

J. Bourriau, 1987. Pottery figures vases of the New Kingdom, in *Cahiers de la Céramique Égyptienne* 1, 81-96.

[21] See Moullou *et al.* 2024, 107-121.

C. Caputo, A. Mandelli, 2023. Digital and Cultural Study of Terracotta Figurines in the Museo Egizio, Turin. The Project SUR.VI.V.E. (SURveying Virtual Voids in Egyptian Collections), in E. Galbois (ed.), Étudier les terres cuites antiques aujourd'hui (assai 1), *Pallas* 121, 79-95.

A. Caubert, S. Fourriet, A. Queyrel, 1998. *L'art des modeleurs d'argile : antiquités de Chypre coroplastique*, vol. 2. Paris.

N. Dell'Unto, 2014. *The Use of 3D Models for Intra-Site Investigation in Archaeology*. Oxford.

P. Del Vesco, B. Moiso (eds), 2017. *Missione Egitto 1903-1920: l'avventura archeologica M.A.I. raccontata*. Modena.

P.F. Dormann, 2002. *Faces in Clay. Technique, Imagery, and Allusion in a Corpus of Ceramic Sculpture from Ancient Egypt*, Münchner Ägyptologische Studien 52. Mainz.

G. Guidi, L. L. Micoli, S. Gonizzi, M. Brennan, B. Frischer 2015. Image-based 3D capture of cultural heritage artifacts an experimental study about 3D data quality, in *Digital Heritage*, 321-324. Granada. [https://doi.org/10.1109/DigitalHeritage.2015.7419514, accessed October, 2025].

J. Huggett, 2022. Archaeological Practice and Digital Automation, in E. Watrall, L. Goldstein (eds.), *Digital Heritage and Archaeology in Practice: Data, Ethics, and Professionalism*, 275-304. Florida.

M. Ioannides, E. Fink, R. Brumana, P. Patias, A Doulamis, J. Martins, M. Wallace (ds.) 2018. *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection, 7th International Conference, EuroMed 2016, Nicosia, Cyprus (October 29–November 3)*, Parts I-II.

J. Kęsik, K. Żyła, J. Montusiewicz, M. Miłosz, C. Neamtu, M. Juszczyk 2023. A Methodical Approach to 3D Scanning of Heritage Objects Being under Continuous Display. *Applied Sciences, 13(1)*, 441, [https://doi.org/10.3390/app13010441, accessed October, 2025].

I. Liritzis, P. Volonakis, S. Vosinakis, 2021. 3D Reconstruction of Cultural Heritage Sites as an Educational Approach. The Sanctuary of Delphi. *Appl. Sci*. 11, 3635 [https://doi.org/10.3390/app11083635].

R. Melendreras Ruiz, M. T. Marín Torres, P. Sánchez Allegue 2021. Comparative Analysis Between the Main 3D Scanning Techniques: Photogrammetry, Terrestrial Laser Scanner, and Structured Light Scanner in Religious Imagery: The Case of The Holy Christ of the Blood. *J. Comput. Cult. Herit.* 15, 1, Article 18, 23 pages [https://doi.org/10.1145/3469126, accessed October, 2025].

B. Moiso, 2008. Le campagne di scavo di Ernesto Schiaparelli in Egitto dal 1903 al 1920, in B. Moiso (ed.), *Ernesto Schiaparelli e la Tomba di Kha*, 199-269. Torino.

C. Morgan, 2022. Current Digital Archaeology. *Annual Review of Anthropology*, 51, 213-231 [https://doi.org/10.1146/ANNUREV-ANTHRO-041320-114101, accessed October, 2025].

D. Moullou, R. Vital, S. Sylaiou, L. Ragia 2024. Digital Tools for Data Acquisition and Heritage Management in Archaeology and Their Impact on Archaeological Practices. *Heritage* 7, 107-121 [DOI:10.3390/heritage7010005, accessed October, 2025].

A.J. Muminović, Ł. Gierz, H. Rebihić, J. Smajić, N. Pervan, V. Hadžiabdić, M. Trobradović, Ł. Warguła, B. Wieczorek, W. Łykowski 2024. Enhancing Furniture Manufacturing with 3D Scanning. *Applied Sciences* 14(10), 4112, [https://doi.org/10.3390/app14104112, accessed October, 2025].

G. Pavlidis, A. Koutsoudis, F. Arnaoutoglou, V. Tsioukas, C. Chamzas 2007. Methods for 3D digitization of Cultural Heritage. *Journal of Cultural Heritage* 8/1, 93-98 [https://doi.org/10.1016/j.culher.2006.10.007, accessed October, 2025].

M. Ramos, F. Remondino, 2015. Data fusion in Cultural Heritage – A Review. I*SPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XL-5/W7*, 359-363, [https://doi.org/10.5194/isprsarchives-XL-5-W7-359-2015, accessed October, 2025].

F. Remondino, 2011. Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sens*. 3, 1104-1138 [https://doi.org/10.3390/rs3061104, accessed October, 2025].

F. Remondino, S. Campana, 2014. *3D Recording and Modelling in Archaeology and Cultural Heritage - Theory and Best Practices*. BAR International Series 2598.

E. Stylianidis, F. Remondino, 2016. *3D Recording, Documentation and Management of Cultural Heritage*. Whittles Publishing.