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The Virtual Reconstruction of the *Aesculapius* and *Hygeia* Statues from the Sanctuary of Isis in *Lilybaeum:* Methods and Tools for Ancient Sculptures' Enhancement

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Abstract: Thanks to recent technological developments in 3D surveys, computer graphics and virtual reality, new scenarios have been opened for the documentation and enhancement of ancient sculptures. When not totally preserved, sculptures can be digitally reproduced, modified and visualized to simulate their physical or virtual reconstruction in a non-invasive way for specialists or for dissemination aims. The virtual sculptural reconstruction process starts usually from the 3D survey of real fragments, and then continues by integrating missing parts with 3D modelling techniques by means of source evaluation. Along with primary data sources (reality-based model), secondary data sources (photos, drawings and 3D models of similar sculptures) can be directly used in the reconstruction process. This approach has a double advantage of making the reconstruction activities easier and less arbitrary, contributing to a decrease in the degree of uncertainty for the sculptural reconstruction work, also thanks to many iconographic comparisons to ancient copies. Moreover, virtual reconstruction can be easily visualized alongside a scalable rendering system using open-source Web3D apps and platforms, accessing information, 3D models and descriptions in order to enhance the experience of artworks. Inspecting theoretical and technical approaches, this work aims at establishing how primary and secondary data sources can be effectively used in sculptural reconstruction workflows, and how 3D outputs can be applied to implement digital sculptural heritage exploitation for museums and cultural institutions. The statues of *Aesculapius* and *Hygeia* from the sanctuary of Isis in *Lilybaeum* (Marsala, Italy) were chosen as a case study.

Keywords: 3D survey; 3D modelling; virtual reconstruction; ancient sculptures; virtual archaeology

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1. Introduction

Virtual reality and computer graphics are considered by specialists in interpretative studies [1] and in-depth diagnostic analyses [2] as precious interaction tools to simulate the physical restoration of ancient sculptures in a non-invasive way [3].

For knowledge dissemination purposes, a digital copy of a statue can also be enriched with descriptions, hypotheses of reconstruction or external links, encouraging an interactive and educational approach for the users [4]. With this aim, as well as traditional itineraries, in the last few years, many museums and cultural institutions have given space to applications, virtual exhibitions and sensorial experiences to enjoy sculptural artworks in a digital way. Cases range from the visualization of 3D models within a neutral scalable environment for multi-resolution models, typical of virtual museums and Web 3D platforms (e.g., Sketchfab), up to ad hoc solutions within historical environments. Examples of these applications were developed in order to simulate a virtual scenario and an augmented reality app recreating specific spaces in the Capitoline Museum in Rome [5] or to evaluate a workflow for the production of historically accurate 3D assets of the Forum of Augustus in Rome, for interactive and immersive virtual reality products [6].

When not totally preserved, sculptures can be digitally reproduced and modified, exploiting the potentialities of 3D surveys and modelling. It is possible to recreate not just the preserved parts but also to model the whole geometry of single damaged sculptures or entire sculptural groups. Digital models of the statues, virtually reconstructed through the scans of their fragments, can be used for critical revisions of reconstructive hypotheses [7]; the digitization of archaeological finds can also be applied to physical and virtual reconstructions for documentation and dissemination in museums [8]. The documentation and investigation of ancient sculptural polychromy is also an important topic in the realization of 3D models of statues [9], i.e., the digital reconstructions of the original polychromy of ancient Greek and Roman artworks show encouraging results that improve the scientific analyses of virtual sculptures [10].

The reconstruction process usually starts from the 3D survey of real fragments (reality-based model or primary data sources) and continues integrating missing parts with 3D modelling techniques in order to create the final model (source-based model) [11]; in this workflow, photogrammetric techniques (integrated with other 3D digital data), 3D modelling and augmented reality application allow digitally overlays of the reconstructed parts of the real sculpture to be achieved [12]. A middle stage between these two main phases (3D survey and 3D reconstruction) is represented by the evaluation of reconstructive hypotheses based on sources of information and comparisons to existing statues (secondary data sources). Interpretative steps in the virtual sculptural reconstruction may take great advantage of a detailed sampling of iconographical types, formulating reconstruction hypotheses more scientifically.

As discussed regarding ancient buildings in relation to the transparency of this process during a virtual reconstruction, the degree of uncertainty mainly depends on the information sources (descriptions, photos, drawings, etc.) [13]. The creation of a conceptual scheme able to clarify the relationship between research sources, implicit knowledge and explicit reasoning represents a fundamental step in order to show the level of uncertainty related to the reconstructive process [14]. However, unlike architecture, the largest diffusion of ancient and modern copies of Greek and Roman statues can contribute to decrease the uncertainty related to the reconstruction process, providing an extraordinary support for Classical specialists, as well as for modellers, who want to recreate the whole geometry of an artwork. Available sources and documents (photos, drawings or 3D models) can in fact be directly used as references in 3D modelling, making the reconstruction activities easier and less arbitrary. The use of sources (such as discoveries made during excavations, pieces from museum collections, historical assumptions and documents from the past) testifies to the lost aspects, as do the 3D survey and stratigraphic reading of the site, representing fundamental steps for the correct archaeological reconstruction [15].

The use of computer-aided design in the field of cultural heritage is largely used for 3D reconstruction and 2D/3D documentation. The 3D virtual restoration of a cultural artefact is a methodology still under development, struggling with the comparison with physical restoration. The latter follows a well-established methodology, with rules, norms and procedures widely accepted and followed, whilst the methodology used in virtual restoration is still under development.

The main issue regarding virtual restoration is related to the transparency of the process. Once the followed methodology is well explained and reproducible, it is easy to understand the main value of restoring cultural artefacts in a virtual environment. The possibility of operating on the heritage without actually touching the archaeological finds allows a trial of different restoration options in order to define the best solution. Moreover, changing the restoration will be possible at all times if some new data are discovered.

Virtual reconstruction, on the other hand, involves the rebuilding of an ancient artefact in a given moment. Hence, it is different from restoration, which is the application of the virtual environment and digital methods in the restoration field [16].

Summarizing, virtual reconstruction is a visual product that shows the hypothetical rebuild of an artefact, whilst virtual restoration considers the shape and the purpose of this artefact, and analyses the best way to complete the missing parts without altering the original object with the assistance of archival data and comparison with similar objects.

This procedure falls into the high value of an inter-disciplinary process. The combination of techniques from different fields helps to obtain a better result in terms of accuracy, both metrological and archival. The most important point to be considered is the reliability of the process, which has to be easily reproduced and improved, if needed. The novelty of the work presented in this paper lays in the meticulous work of combining all the sources with a philological methodology that takes into consideration the different information levels of the sources used.

Inspecting theoretical and technical approaches, the work aims to establish how primary and secondary data sources can be effectively used in virtual sculptural reconstruction workflows and how 3D outputs can be applied to implement the sculptural heritage's digital exploitation for museums and cultural institutions.

The proposed workflow is applied to the virtual reconstruction of the *Aesculapius* and *Hygeia* fragmentary Roman statues found during excavation activities in the Archaeological Park of "Lilibeo" (Marsala, Italy). The Park preserves the archaeological remains of *Lilybaeum*, an ancient Punic settlement in western Sicily.

In the last years, the University of Palermo has carried out several 3D surveys in the Archaeological Park of "Lilibeo" in order to digitize all the main architectural remains [17,18], such as the ancient ruins of the sanctuary of Isis [19] where the statues analysed in this paper, actually exhibited in the Museum of "Lilibeo", come from. The virtual reconstruction of the statues is therefore part of a wider project aimed at enhancing and explaining the history of the sacred building to scholars but much more to museum visitors.

The paper is organized as follows: in Section 2 there is a description of the statues of *Aesculapius* and *Hygeia* and some information about the archaeological context; in Section 3, the virtual reconstruction workflow of the sculptures is presented; a discussion on 3D model visualization systems by means of a virtual reality solution for museums and cultural institutions is described in Section 4; finally, concluding remarks and future applications are reported in Section 5.

2. The Statues of *Aesculapius* and *Hygeia* from *Lilybaeum*

The ancient city of *Lilybaeum* was founded by the Punics in the 4th century B.C. after the destruction of Motya in 397 B.C. Founded as a Carthaginian military stronghold, the city was famous for its fortifications, equipped with towers and a moat, and walls with thickness at some points of up to 6 m and height approximately 9 m. It withstood the siege by Pyrrhus (276 B.C.), a first assault by the Romans in 253 B.C. and the following eight-year siege at the end of the First Punic War (250–242) when the Romans finally conquered the city after the battle of the Egadi and the peace of Eryx (242 B.C.). After the Roman conquest, the city preserved its military and commercial rule during the Republican and Imperial Ages. Cicero lived in *Lilybaeum* when he was quaestor of Sicily and he described the city as *splendidissima civitas lilibetana* (splendid city of *Lilybaeum*). At the time of the emperor Pertinax, the city was reduced to a colony, *Helvia Aug. Lilybaitanorum*.

At the present time, the remains of the ancient city of *Lilybaeum* are preserved inside the Archaeological Park of "Lilibeo", which extends for 28 hectares surrounded by the modern city of Marsala (Sicily, Italy) (Figure 1).

The urban ancient city plan was divided by primary (*plateiai*) and secondary streets (*stenopoi*) organized along an orthogonal grid. The length of the blocks is not yet known, but they measured about 30 m on the short side, as found in the northeast sector of the city where three blocks were excavated (*insulae I–III*). Luxurious homes, with private baths,

occupied blocks I–II in Roman times. At the same time, *insula III* was occupied by a sanctuary dedicated to the goddess Isis.

Figure 1. Archaeological Park of "Lilibeo" inside the modern city of Marsala (Italy) (from Google Earth©).

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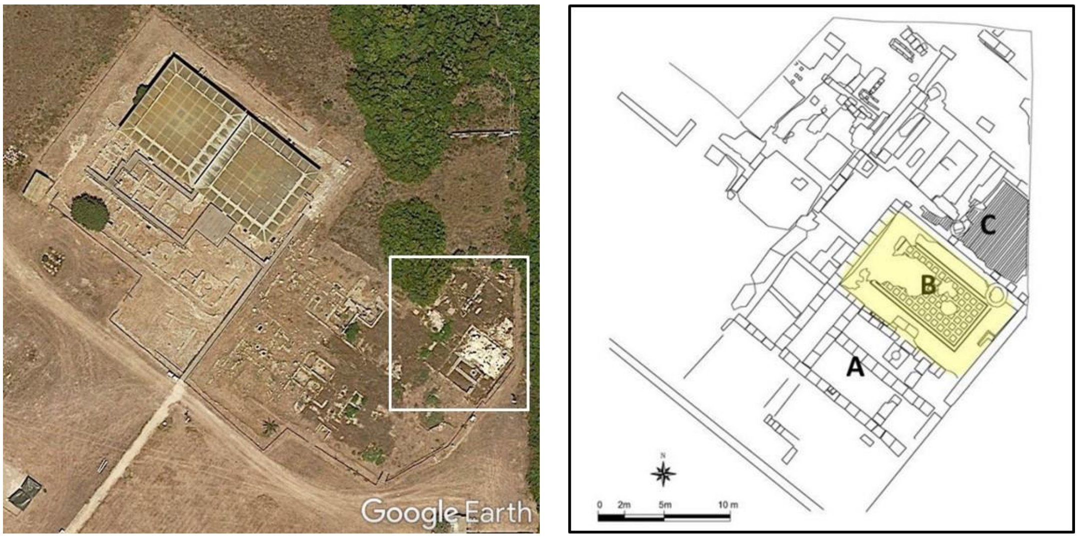
The sanctuary of Isis was built during the late republican period (2nd century B.C.). The temple was probably composed firstly of a single internal room, then subdivided into three interconnected rooms in the last building phase (2nd–3rd centuries A.D.) (Figure 2).

The core of this plan was the central room (room B) paved with a polychrome mosaic with geometric decoration (7.80 m $\times$ 12.20 m), widely patched in the past with inserts of marble slabs (Figure 3) [20]. Along one of the short sides was a small podium, perhaps paired off with another one to the opposite wall for the exposition of the cult statues.

Many fragments of epigraphs and marble statues were found during two archaeological campaigns; one of the most interesting was the small column with a dedication to the *myrionimos* (thousand names), epithet of Isis goddess, to which the temple seems to be dedicated. Into the sculptural group, two fragmentary life-size statues, identified as the couple formed by *Aesculapius* and *Hygeia* (health deities), were paired and shown to the public (since March 2017) in the Archaeological Museum of "Lilibeo" (Figure 4).

The statue of *Aesculapius* consists of two not perfectly matching large fragments (max. height 110 cm; max. width 54 cm; max. thickness 32 cm), broken at the pelvis, and a small fragment of a shod foot. Head and arms, pectoral muscles and lower limbs down to the knees are lost. The statue shows the image of a god standing on his right leg whilst the left one is slightly bent, bare-chested and with part of a cloth rolled up on the hips, with a flap falling from the left shoulder. In the lower part, vertical folds model the draping.



(**a**) (**b**)

Figure 2. View of the *insulae I–III* (from Google Earth@) showing the area of the sanctuary of Isis (**a**); plan of the sanctuary of Isis with the three interconnected rooms (room A, room B and room C) (**b**).

Figure 3. Ruins of the sanctuary of Isis in *Lilybaeum* from SE.

Only a fragment of the torso (max. height 61 cm; max. width 54 cm) of the *Hygeia* statue survives. Even in this case, the head, the arms and the lower part down to the thighs were not preserved. The statue shows the image of a standing goddess dressed in a long peplum with a high knot falling from the right shoulder.

The backside of both statues is roughly hewn due to the probably ancient placement in a niche or against the wall in the mosaic room above two podiums.

Figure 4. Statues of *Aesculapius* and *Hygeia* from the sanctuary of Isis in *Lilybaeum*.

3. Virtual Reconstruction Workflow for Sculptural Fragments

The surviving fragments of the statues, known as Special Finds (SFs) in archaeological practice, can be directly involved in the modelling procedures as a starting point for the model geometry detection and to support the realistic reconstruction hypothesis as primary data sources [6,15]. For this reason, the creation of a SFs' reality-based model is the first step in almost all virtual sculptural reconstruction projects. Three-dimensional survey techniques are usually oriented to the object features or a specific level of detail; high-resolution 3D models with millimetre or submillimetre detail for diagnostic scopes can be reached both with range-based and image-based techniques, often also integrated [11,21,22].

According to the type of document, secondary data sources can be usually classified in two main categories: 2D sources (drawings, photos, illustrations, etc.) and 3D sources (3D models of similar statues from web platforms or properly acquired). Along with primary data sources, 2D and 3D secondary data sources pertaining to comparative sculptures can also be directly used in the integrative modelling reconstruction process. Secondary data source collection must be recognizable in order to be more strictly applied in workflow steps and to assure the transparency of the process by means of source tracking [14].

Once collected, both primary and secondary data sources flow into the modelling phase and are adapted in order to create a single final model (source-based model). According to the 3D visualization infrastructure, the sources and processes behind reconstruction can be shown by means of a real-integrated model. In this way, it is possible to distinguish the surviving fragments from the modelled ones through an original texture, which can even be omitted and replaced by a uniform new texture that mimics the hypothetical original state of sculptures.

The workflow is divided into three steps (Figure 5):

1. primary data sources' acquisition: 3D survey and reality-based model creation;
2. secondary data sources' collection: acquisition and evaluation of reconstruction hypotheses;
3. 3D modelling and source-based model creation.

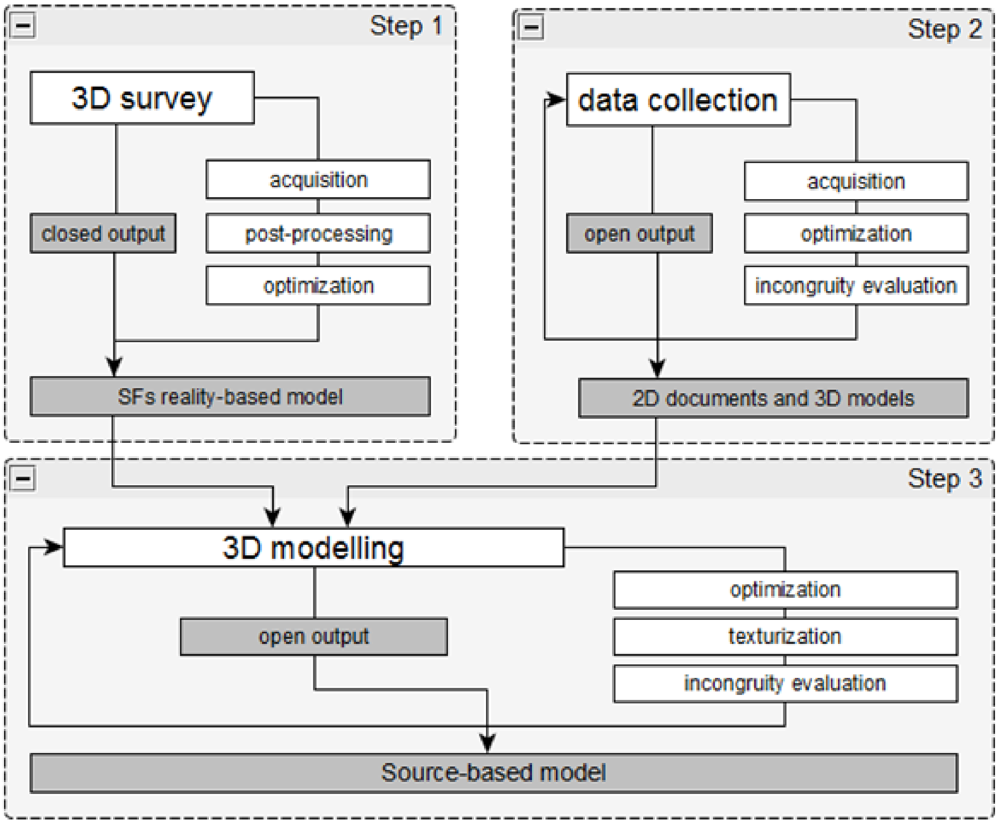


Figure 5. Virtual sculptural reconstruction workflow.

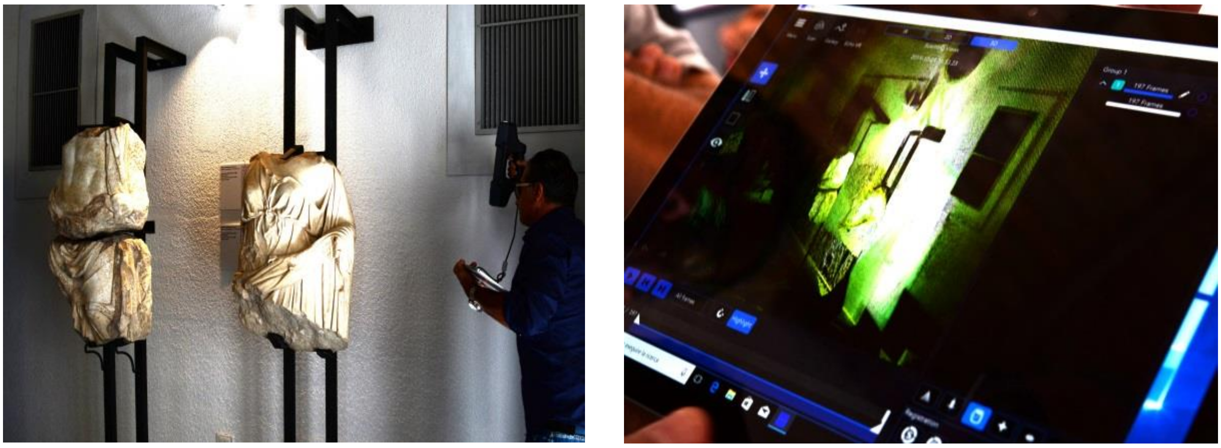
3.1. Primary Data Sources' Acquisition: 3D Survey and Reality-Based Model Creation

The 3D survey can be performed using both range-based and image-based techniques; the choice depends on various conditions such as the size of the object, the location, etc. Range-based techniques are generally the most reliable for large sculptural groups, but, in most cases, they show limitations in reproducing the chromatic features, unlike image-based techniques, which are able to capture realistic textures and high detailed models starting from a series of high-resolution images. For this reason, in order to achieve the best results from 3D survey techniques, range-based and image-based techniques are often integrated.

Prior to starting the survey, a few elements were considered: the state of conservation of the statues, their sizes and type of material, their position in the museum hall, and the lighting conditions. The most critical aspect of the survey was the position of the statues, which were very close to the wall.

In order to prevent any problem, the 3D survey was conducted with both range-based and image-based techniques. A range-based survey was carried out first using the Stonex F6 3D handheld laser scanner; this device allows the acquisition of 3D models of medium–large objects in dynamic motion. The survey was carried out with an average distance between the instrument and the statues of about 50–60 cm. The execution was supported via tablet by real-time data visualization (Figure 6). The laser scanning survey allowed the acquisition of point clouds of the entire statues with an average resolution of a few millimetres. After the acquisition, 3D scans of *Aesculapius* and *Hygeia* statues were processed with the Stonex-Echo software that produced very detailed 3D meshes.

A close-range photogrammetric survey was carried out using a Nikon D5200 digital camera, equipped with 24–55 mm lenses and a maximum resolution of 6000 × 4000 pixels. Image acquisition was carried out with a 24 mm focal length by executing a very close-range convergent acquisition. For the statue of *Aesculapius*, a total of 55 images were required; for *Hygeia*, a total of 48 images were needed. Smaller fragments—one female and one male shod foot—were also acquired. In Table 1, details of the photogrammetric survey are reported.



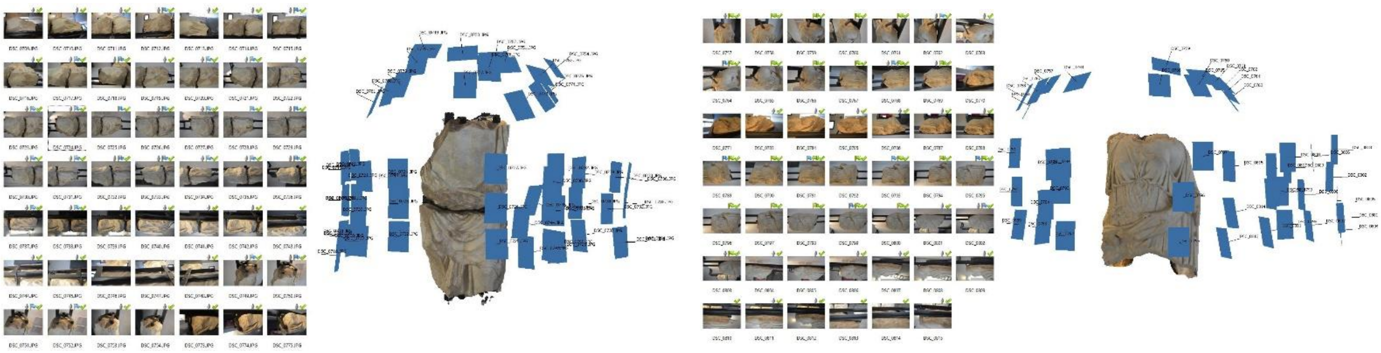
(**a**) (**b**)

Figure 6. 3D laser scanner survey of the *Aesculapius* and *Hygeia* statues: (**a**) Stonex F6 acquisition; (**b**) real-time visualization.

Table 1. Details of the photogrammetric survey of the Special Finds.

Special Finds	N. of Images	Focal Length
Aesculapius statue	55	24 mm
Hygeia statue	48	24 mm
Aesculapius right foot	24	40 mm
Hygeia left foot	34	55 mm

Images were processed with the Agisoft-Metashape package. Image alignment was the first step; then a dense point cloud and a textured mesh were generated (Figure 7). Some distances were measured on the laser scanner models in order to scale the photogrammetric models. The same photogrammetric process was carried out for smaller fragments but the scaling procedure was performed by applying one or more scalebars into the scene during the survey.

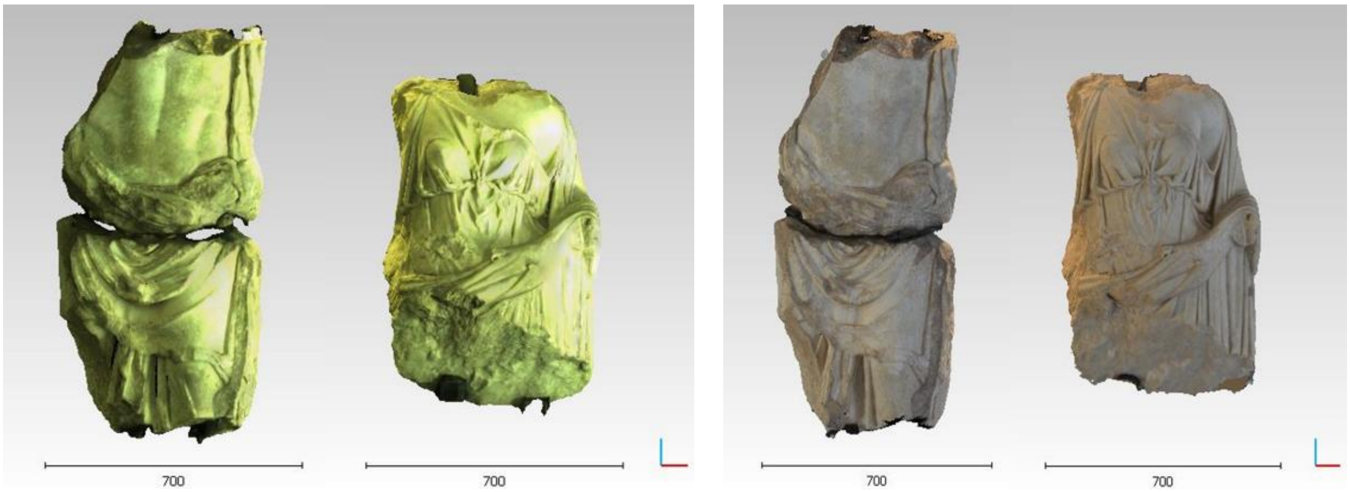


(**a**) (**b**)

Figure 7. Agisoft-Metashape photo alignment step of the *Aesculapius* (**a**) and *Hygeia* statues (**b**).

The models generated for both statues using photogrammetric techniques were conducted to the same reference system of the laser scanner 3D model, by a cloud-to-cloud registration using CloudCompare and the "Fine registration" tool. This tool can automatically finely register two different point clouds or meshes using a modified ICP (Iterative Closest Point) algorithm able to also determine a potential difference in scaling between the two datasets.

Two 3D models from the handheld laser scanner and photogrammetry for both statues were thus obtained (Figure 8). The two-point clouds were merged to fill some holes in both datasets. The final point clouds were then sampled in order to obtain 3D models of about 200,000 polygons.



(**a**) (**b**)

Figure 8. Three-dimensional models of the *Aesculapius* and *Hygeia* statues carried out by means of Stonex F6 3D handheld laser scanner (**a**) and photogrammetric survey (**b**).

3.2. Secondary Data Sources' Collection: Acquisition and Evaluation of Reconstruction Hypotheses

To reconstruct the virtual geometry of a statue starting from its surviving fragments, in some cases, it may be sufficient to combine the digital SFs' models through 3D modelling techniques. However, due to the gaps of the missing parts, multiple sources of information can contribute to achieving the hypothetical shape of the entire statue thanks to comparisons with known classified originals and copies.

The research of sources for the hypothetical reconstruction of ancient sculpture is a widely inspected field of study by specialists of Classical sculptures. The philological approach used in tracing the sources makes it possible to obtain stylistic and chronological information about the sculptures, as well as to hypothesise on lost features. Source tracking is fundamental to formulate reconstruction hypotheses more scientifically and to define the degree of uncertainty of virtual reconstruction work. The collected 2D and 3D documents (photos, drawings or 3D models) can be effectively used for virtual sculptural reconstruction not only in the interpretative step but, as described below, also in the modelling step.

Existing statues iconographically similar to the *Aesculapius* and *Hygeia* sculptures from *Lilybaeum*, but almost entirely preserved, are thus identified. Many of these statues date back to the second century A.D and come from the North African area, especially from thermal buildings (due to the symbolism, which identifies the divine couple to the health protection). For each one of these, related 2D and 3D documents were classified as secondary data sources. In particular, two sculptures from the Temple of *Aesculapius* and *Salus* in *Lambaesis*, capital of Roman Numidia in Algeria, show the closest similarities to the Lilibetan statues, with the same rotation of the pelvis, the position of the legs and treatment of the pectoral muscles for the male statue, and the same dressing for the female one. For this reason, their images (D. *Ae.* 10, D. *Hy.* 03) were used as the main reference during modelling activities.

Further comparable 3D models were also identified on web platforms, as reported in Figure 9.

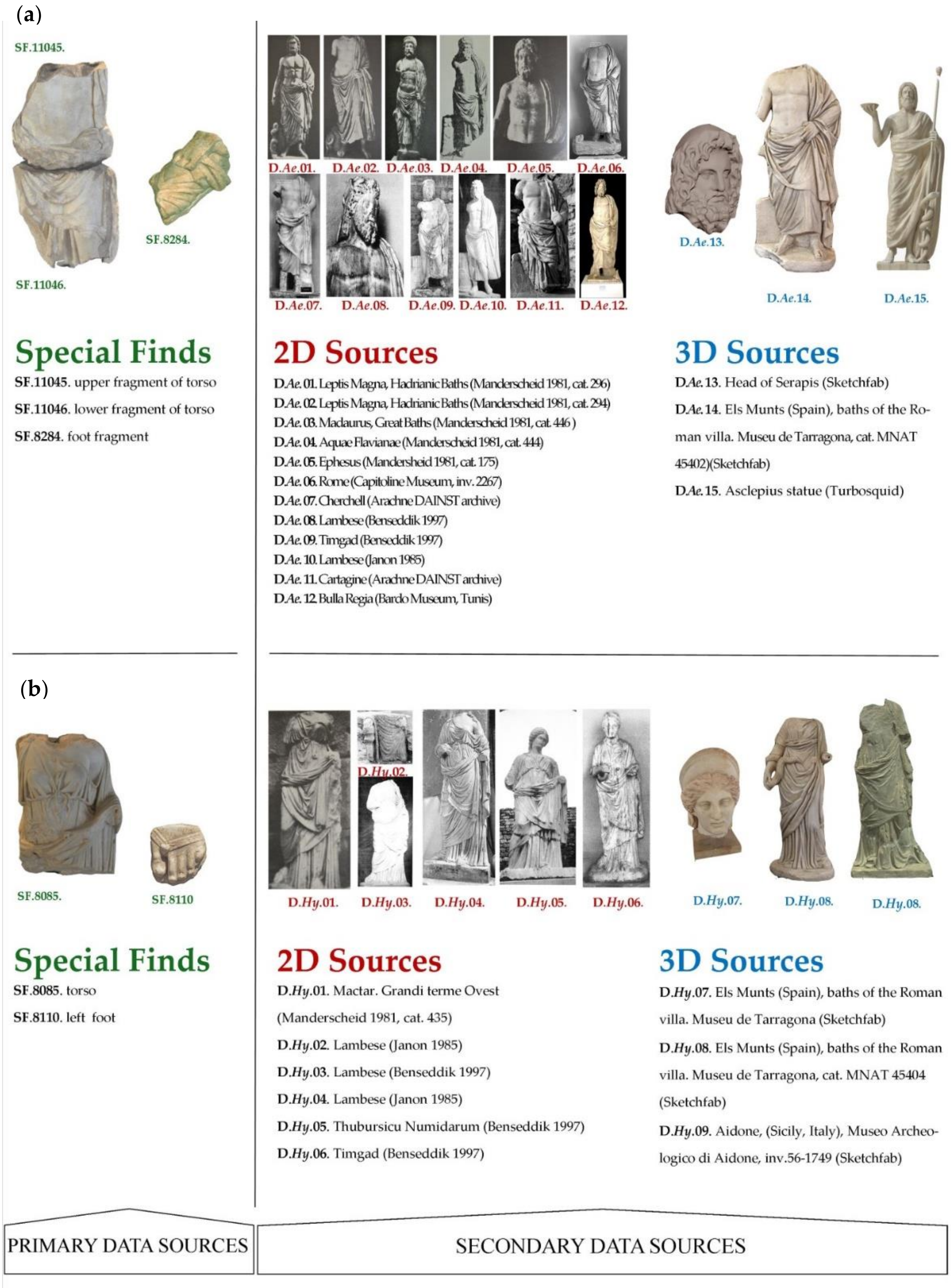


Figure 9. Schemes of input data: collection of primary and secondary data sources for the *Aesculapius* (**a**) and *Hygeia* (**b**) statues' virtual reconstruction. For SFs are provided museum inventory numbers; documents of secondary data sources are instead identified using progressive numbers for both 2D and 3D sources.

3.3. 3D Modelling and Source-Based Model Creation

The combination of multiple sources in a virtual sculptural reconstruction process must take into account problems related to the scale and geometry of the involved documents.

In fact, all selected secondary 2D (photos or drawings) and 3D sources (meshes) should be scaled over the main SFs' reality-based model prior to starting the modelling phase, in order to achieve the right proportions between different models.

Scaling procedures can be directly conducted in the modelling software both for 2D and 3D sources models, balancing proportion referring to the main SFs' mesh and adjusting scale from different perspectives. Scale optimization may also be provided for a procedure of mesh registration between the SFs and secondary sources. It should be considered that sources images used as modelling references are merely indicative of the final geometry and non-binding, especially when images are affected by strong optical distortions. Moreover, for 3D sources, even if models are geometrically correct, they could be affected by deformations due to the original sculptures themselves, compromising an easy integration between different sources.

When 3D source meshes are imported, a preliminary polygons count decimation or retopology can also be considered in order to improve and make easier the management of multiple meshes. They can be superimposed to the SFs' mesh and segmented along with fractures of the reality-based model to isolate fragments useful for the integrations. Then, mesh segments can be joined to the reality-based model by merging vertices of meshes into a single model (source-based model). For this scope, the "Live booleans" tool in the Pixologic Zbrush package can be useful to easily merge different meshes into a single model after sectioning them. Sculpting tools are also essential to refine some model details, especially smoothing meshes along the fractures. Once the geometry of the whole statue is reconstructed and optimized with a further decimation process to increase the meshes regularity, the creation of two versions, high and low poly, of the source-based model is recommended for future different applications and scopes (Table 2).

Table 2. Polygon count source-base models: meshes details of the high and low poly models after decimation.

Models	*Aesculapius* Statue	*Hygeia* Statue
High poly source-based model	1,077,189	748,009
Low poly source-based model	206,364	207,718

As Figure 10 shows, the high poly source-based model of the *Aesculapius* statue is reconstructed using the meshes of the two main SFs pertaining to the torso and the upper part of the legs (SF. 11045, 11046) and a fragment of a shod foot (SF. 8284). Integrations are mainly carried out thanks to the 3D model of another *Aesculapius* statue (D. *Ae.* 14) coming from the baths of the Roman villa of Els Munts (Tarragona, Spain) and a head of *Serapis* (D. *Ae.* 13), both available on Sketchfab. According to their similarities, the god of medicine is reconstructed with a long beard and hair; the snake, symbol animal of the god, is wrapped on a long stick on his left hand. The source-based model of the *Hygeia* statue is instead created starting from the main fragment of the torso (SF. 8085) to which are integrated segments of 3D models pertaining to one female head from the Roman villa of Els Munts (D. *Hy*. 07) and a female statue from eastern Sicily, exhibited at the Archaeological Museum of Aidone (Italy). Even in this case, the source of the 3D models is the Sketchfab platform.

For the high poly models of the *Aesculapius* and *Hygeia* statues, integrations can be clearly distinguished by the real fragments just using textures of the SFs' meshes, according to the theory of restoration and the transparency of virtual reconstruction (Figure 11). However, considering possible declinations for a virtual scenario (e.g., gamification, treasure hunts, itineraries for children, etc.), original textures are not always required, but they can be replaced by new textures simulating original materials. For this purpose, a low poly model was carried out sampling the high poly and then processed following a further step adding a new texture that could be considered as "ideal". Its features are established according to the original surface material of sculptures (grain or marble veins) and reproduced using the right values of roughness, glossiness and smoothing in the Adobe Substance package (Figure 12).

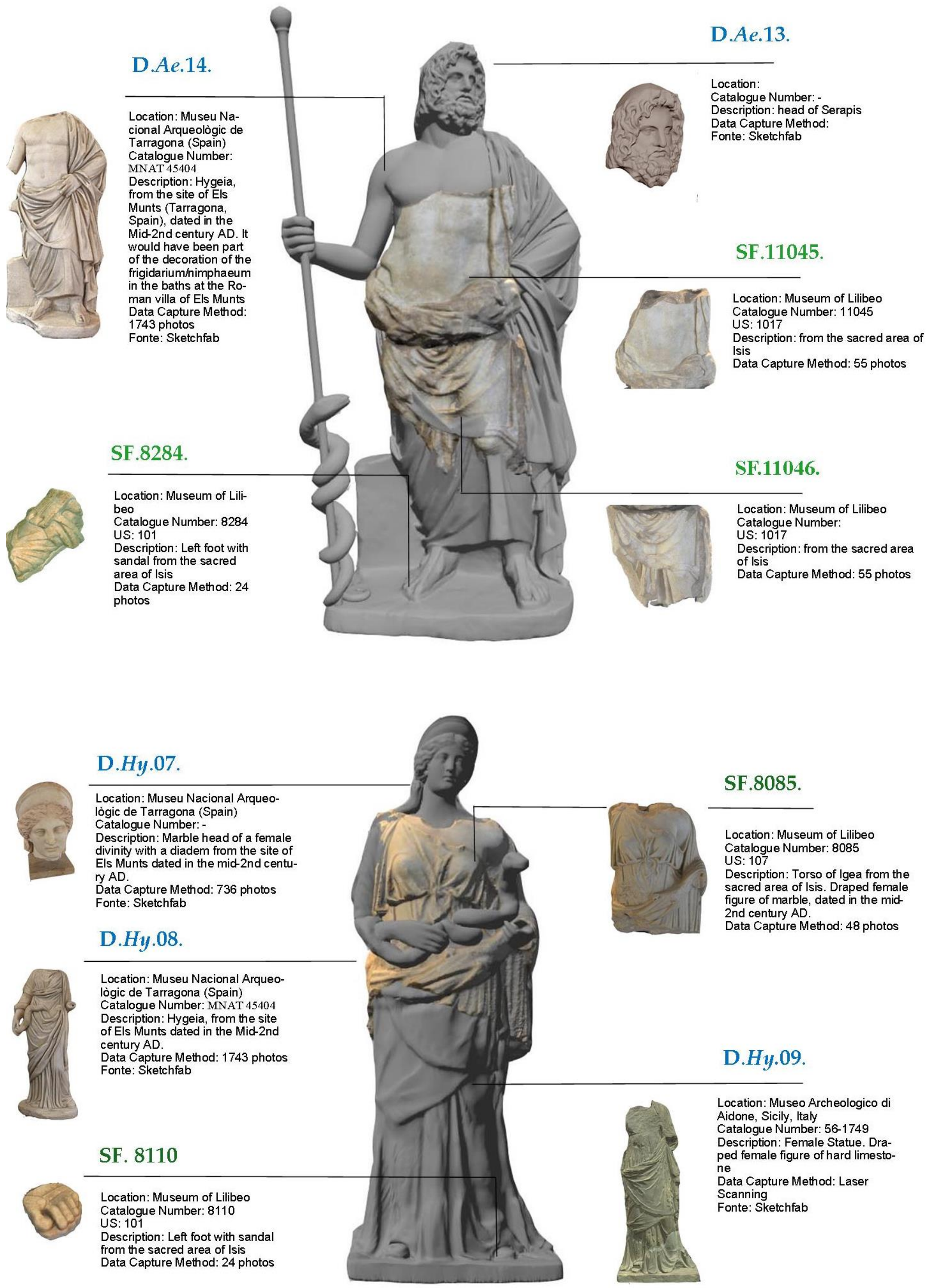


Figure 10. Virtual reconstruction of the *Aesculapius* and *Hygeia* statues: high poly model with source tracking.

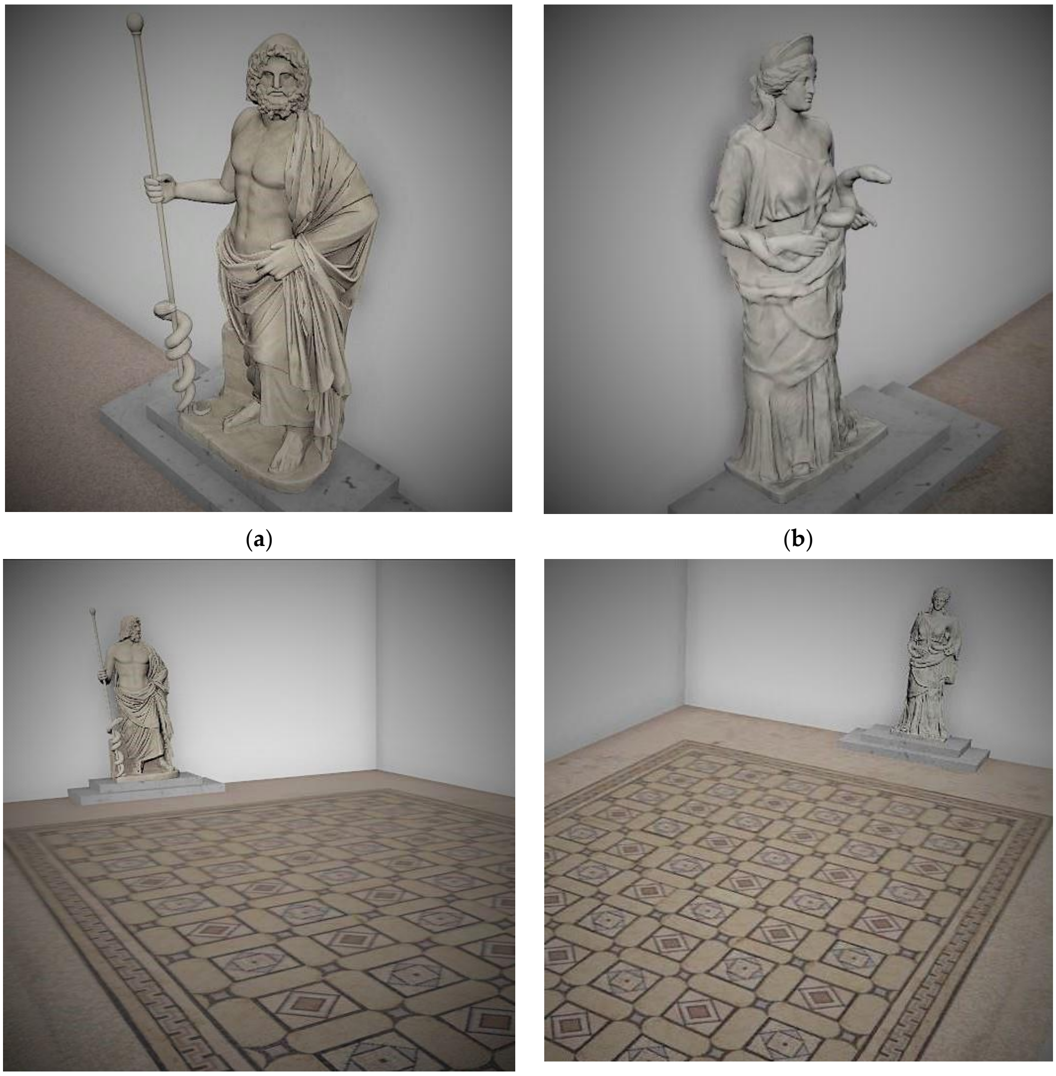
Figure 11. Close-up view of the *Aesculapius* and *Hygeia* statues high poly models.

Figure 12. Rendering of the low poly models of the *Aesculapius* and *Hygeia* statues.

4. Visualization Tools

Since the beginning, work was oriented on two visualization mode solutions for both statues of *Aesculapius* and *Hygeia*: a presentation of the reconstructed statues inside their supposed original place in the sanctuary of Isis and a view of each statue within a neutral setting aimed at highlighting the adopted virtual reconstruction process.

In the first case, the historical scenario was recreated providing the idea of the space for which sculptures were originally conceived. The virtual reconstruction of the sacred building (already conducted for the main architectonical parts of the sanctuary of Isis such as walls, mosaic and *opus spicatum* floors) was based on excavation data related to stratigraphic and volumetric information and on the existing data of the structures and SFs from the same site [19]. Starting from the 3D model of the sanctuary of Isis, within the scenario of the central mosaic room, probably the *cella* of the temple, the statues (low poly models) were hypothetically positioned on two podiums on the short sides of the room using the Maya rendering package (Figure 13).



(**a**) (**b**) (**c**) (**d**)

Figure 13. Hypothetical reconstruction of the archaeological context (*cella*) with the placement of the statues on the podium: (**a**,**b**) hypothetical top-view and (**c**,**d**) distant view of the statues on the podium inside the mosaic room.

In the second case, the presentation of the 3D contents relating to the statues of *Aesculapius* and *Hygeia* was performed by means of the ATON tools framework (developed by B. Fanini for CNR-ISPC) that allows the creation of Web3D/WebXR apps interacting with cultural heritage objects and 3D scenes inside a scalable rendering system with responsive interfaces [23]. With no installation required and using common web browsers and modern web standards descriptives, 2D and 3D contents can be easily stored and visualized on different devices (mobile, desktop/kiosk or immersive VR) [24]. Solutions like this can be used by different cultural institutions (museum, archaeological areas, etc.) allowing a broader diffusion and involvement of networked information and objects for rich interactions and easy implementation, in order to create collections for public access. Currently, the web-app contains several 3D models, many of them publicly available on https://aton.ispc.cnr.it (accessed on 7 March 2022), and the framework flexibility for different needs and case studies, and the scalable front-end (*Hathor*) for the open-access contents suggest the adoption of this technology on a large scale in the future. Actually, some models relating to the statues of *Aesculapius* and *Hygeia*, and their reconstructed hypothesis, are already accessible in a private collection using a personal ID and password. Entering the login credentials, the current display leads to a main gallery of the collected models (Figure 14).

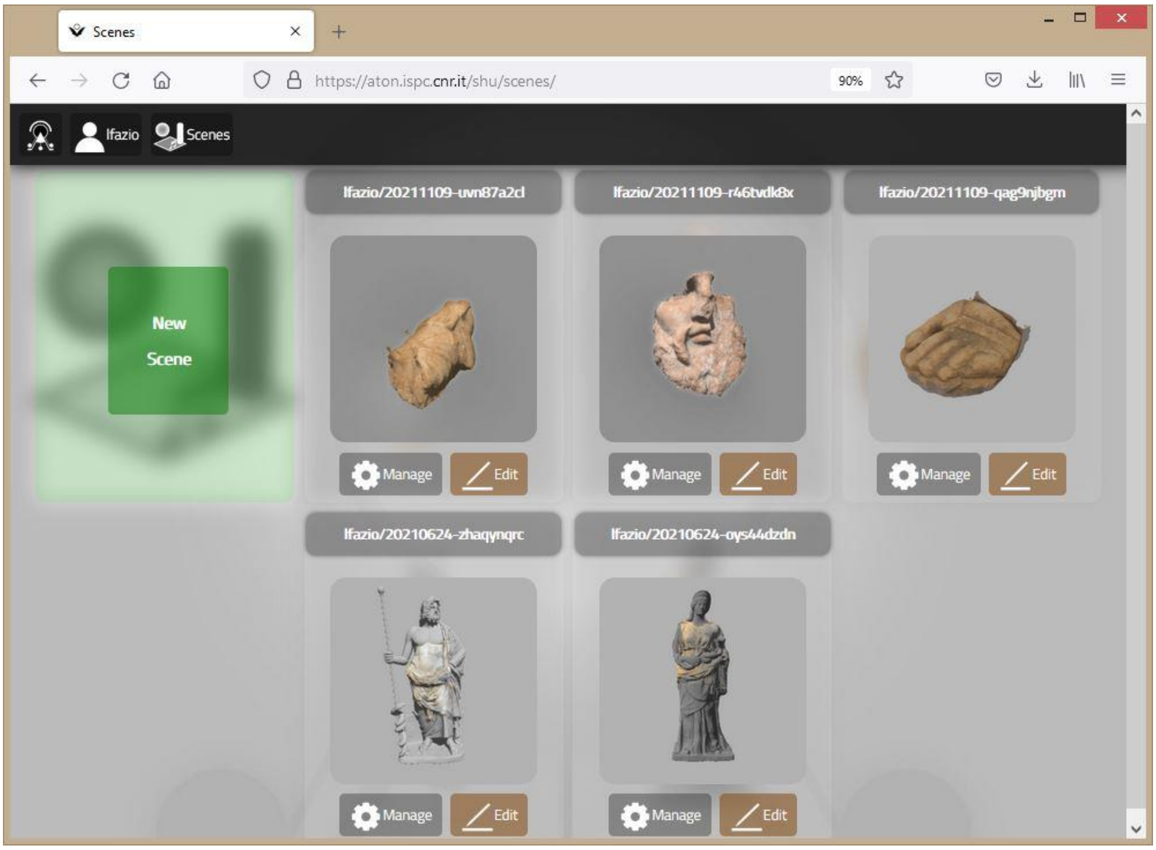


Figure 14. ATON front-end on standard browser for scenes gallery.

Once the 3D object is selected, a description of the artwork is shown; then, the user can deepen his knowledge of the object through several levels of visualization, from the real 3D model to the reconstructed model, thanks to the superimposition of different layers (Figure 15).

Through the ATON web browser, the enhancement of sculptures and their archaeological context was addressed to the creation of a "Multimedia catalogue" of the SFs from the sanctuary of Isis using multimedia contents and descriptive information. The "Multimedia catalogue" will be publicly accessible via personal devices (smartphones, tablets etc.) inside the museum (Figure 16) or directly on site, near to the archaeological ruins of Isis' sanctuary through a web browser or QR codes strategically positioned.

(**a**) (**b**) (**c**)
(**d**) (**e**) (**f**)

Figure 15. ATON front-end on web browser for computer desktop, textual data sheets (**a**,**d**), view of the reconstructed models (**b**,**e**), 3D real models (**c**,**f**) of the statues of *Aesculapius* and *Hygeia*.

Figure 16. The room inside the Museum of the Archaeological Park of "Lilibeo" with finds from the sacred area of *insula III* exhibition.

5. Conclusions and Future Works

Today, methods and tools allow the extension of previous approaches in virtual sculptural reconstruction involving artworks into a new perspective, communicating enriched 3D contents using common web browsers and interacting with 3D models from mobile devices, multi-touch screens, kiosks, and immersive VR without any installation required by visitors.

The enhancement of sculptural heritage can take benefits from new technologies that can be applied to projects aimed at attracting the different categories of users that today are part of the museum's public. In this study, the fragmentary Roman statues of *Aesculapius* and *Hygeia* from Lilibeo were used to develop a process by a rigorous workflow for sculptural artwork reconstruction, where digital models with different features and levels of details are carried out. The sculptural finds of *Aesculapius* and *Hygeia* were digitized and manipulated in order to recreate their original form combining 3D survey and modelling technologies in order to highlight the relation between real fragments and integrative parts. For each step of the workflow, well-established methods and tools are provided. In a 3D survey, both photogrammetry and handheld laser scanner techniques are used in order to integrate different 3D models. From a practical point of view, the union of the 3D reality-based models from image and range-based techniques allowed a first highly detailed model of the sculptural fragments to be acquired. The possibility of simplifying high poly models by means of sampling and retopology procedures allows adaptation of the 3D outputs of the reconstruction work for various purposes. However, the main innovations and advantages of the workflow are related to 3D modelling. New tools are available in modelling software, such as "Live Booleans" in Zbrush package, very useful for integrating 3D models from different origins, or very responsive sculpting tools for closing mesh holes or smoothing surfaces, and streamlining the workflow from the merging of meshes to generating final outputs.

The reconstruction process can be considered as a proven procedure for specialist studies such as in restoration and diagnostic, or employed for non-scientific aims improving the attractiveness of the museum collection and enhancing archaeological sites and artworks also creating shared and accessible archives of 3D models on the web. After the COVID-19 crisis, new resources and methods of use can be implemented; the combination of information, images and 3D models, interactively manipulated by the users through web browsers on their personal devices permits visitors to explore virtual scenarios and objects independently.

In order to preserve as much as possible archaeological data and information of stratigraphic units, further developments will be including the use of the Extended Matrix tools [25]. This method allows representing a context in a given epoch and in an explicit hypothesis from all available data, offering a synthesis of chronological phases, relations between structures and objects into the same scene. In this way, the information on sculptural SFs can also be kept and displayed in the virtual environment, providing for more transparency in the reconstruction process.

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