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3D Digital Imaging for Knowledge Dissemination of Greek Archaic Statuary

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Abstract

This paper aims, using a research exercise, to verify the association between two Greek sculptures collected at different times: the head of a boy collected in the Chalcidian colony of Leontinoi in southeastern Sicily, acquired in the 18th century and later kept in the collection of the Museum of Castello Ursino in Catania, and a torso, retrieved in 1904 and since then displayed in the Archaeological Museum of Sicily. The two pieces share similar stylistic features and represent the most significant example of Greek sculpture in Sicily at the end of the 6th century BC. Their association is an open problem still debated by scholars, who have based their studies on comparisons between pictures as a reassembly of two artefacts was never attempted. This critical issue has conditioned curators of the two museums, who could not develop a proper communication policy for the two objects, resulting in a limited cognitive accessibility for the public. By means of 3D scanning techniques, this contribution showcases how virtual restoration can not only improve interpretations of the scholars, but also boost the communication plans of museums, giving back to the public via a web platform a masterpiece of Greek sculpture known just by specialists.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

1.1. The endangered archaeological heritage

The fact that archaeological heritage, as a physical remnant of past and lost civilizations, has come to us after millennia, and in many cases, in decent condition, despite all the forces that threatened it, does not allow us to take for granted that we will be able to pass it as it is to the next generations. Never in the current time of archaeology of any scale, from artefacts to sites to landscapes, has it been so endangered by old and new enemies. The destructive force of nature has demonstrated several times how an entire site can be annihilated in a short lapse of time causing irreparable damage, especially in those countries rich in archaeology but poor in technical knowledge. Two shocking examples, which unfortunately did not have a great coverage on the media, are represented by the Iranian citadel of Arg-e Bam (3^{rd} BCE - 3^{rd} CE), a $200,000$ m^2 complex made of sun-dried mud brick, wiped off the map by a magnitude 6.5 earthquake in 2003 [NSS*05] and by the complex of $1,400$ temples of the Shwedagon Pagoda (6^{th} - 10^{th} CE), in the Irrawaddy Delta region of Myanmar, which were razed to the ground by a cyclone in 2008 [See09]. Notwithstanding, a natural disaster is not enough to raise public awareness of the transience of archaeological heritage. In fact, in our collective memory there is still room to remember the devastations caused by terrorist groups in Afghanistan, Iraq and Syria, who, in the last 15 years, destroyed world heritage sites and monuments of splendid civilizations spared by millennia making archaeology another casualty of their madness [Cur11]. Statuary is often targeted because its realistic imitation of reality goes against the religious principles of those radical groups. However, there are other threats which can condemn the archaeological heritage to the oblivion without harming it physically or being criticized and publicly denounced. Wrong and short-sighted governmental decisions have sacrificed knowledge and public outreach on the altar of best practice in business and politics [Vin]. An emblematic case is represented by the Greek statue known as the Goddess of Morgantina [Zis, Cev09], a masterpiece of Late Severe Style sculpture (half of 5^{th} century BC) illegally excavated in the ancient Greek city of Morgantina (Sicily) in the late 70s and purchased in 1988 by the Getty Museum. In 2011, once its Sicilian origin was established on the basis of archaeometric analyses, the statue was sent back to Italy and installed in the museum of Aidone (Enna). The comparison between the average number of annual visitors of the two museums in 2014, 1.3 million at the Getty Museum at the Getty Center

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and 5.000 at the Museum of Aidone, clarifies how the request of the Italian government to recover the statue has reduced this artefact to a state of very limited visibility and accessibility. More iconic is the case of another statue, the Venus of Cyrene [Cev11], dated to 2th century AD), found in 1913 by Italian archaeologists in the sanctuary of Apollo at Cyrene, when Lybia was an Italian colony, and subsequently delivered to Italy and kept in the Museum of the Baths of Diocletian at Rome. In 2008, in the frame of an economic agreement between the Italian and Lybian governments, Italy sent the Venus of Cyrene back to Lybia. The delivery took place during a great ceremony at Bengasi, where the statue was presented before being sent to the Museum of Tripoli. The Venus of Cyrene never made it to the Museum of Tripoli and during the first civil war in 2011 the statue vanished. In this case, a political decision has produced the same outcome of a bomb. In certain countries with a rich past and an abundance of archaeological monuments, another plague is represented by the illegal excavations and international trafficking of archaeological artifacts, a phenomenon which in Italy, and especially in Sicily is considered one of the emerging fields of interest of criminal organizations [Har11]. Archeomafia, as it is commonly called, endangers not just archaeological artifacts still buried in poorly defended sites or parks but also those safe and sound in the collections of well-known museums [leg].

1.2. Miscommunication issues and limited cognitive accessibility

A serious threat, which is rarely considered as deadly as all the others mentioned above is the lack of awareness by the public of the importance of a certain archaeological artefact or monument [Kno93]. In fact, in people's view relies the pivot for every monitoring, protecting and developing policy. The overwhelming scientific literature production does not follow a communication plan aimed to reach the general public with equal force, causing as a consequence a general indifference if not a total ignorance. If an archaeological artefact is not properly communicated, if its importance is not fully grasped, it will be hard to see it properly protected, promoted and eventually transformed into an economic asset as touristic attractor. This state of things often results in cases of museums having remarkable pieces in their collections, which are marginalized because their role in ancient art is well known to scholars. but unknown to the general public. As a response to this scenario, this paper focuses on a problematic case study represented by two matching pieces of a statue, kept in two different museums, the reputation of which can be restored via an exercise of virtual restoration.

2. The case study: an Archaic kouros from Leontinoi?

2.1. The "Biscari head" and the torso from Leontinoi

Greek Archaic sculpture is dominated by the production of statues of young naked boys, so called *kouroi* (plural of *kouros* meaning in Greek "boy"), and young girls with long vests, named *korai* (plural of *kore* meaning in Greek "girl"), having religious or funerary significance and for this reason generally offered as ex voto in sanctuaries or placed above or by tombs in cemeteries [Ric60]. The statues were the symbolic representation of the worshippers consecrating their lives to the deities or idealized portraits of the dead. Their widespread distribution in the Greek Mediterranean between the end of 7^{th} and the early decades of 5th century BC testifies to the fortune of these iconographies which summarized the concept of kalokagathia, the combination of virtues - goodness and excellence - to which Greek civilization was devoted [And07]. In Greek Sicily, there are several remarkable examples of kouroi and korai imported from Greece or locally produced, and some of them can certainly be considered as masterpieces of Greek statuary [DM]. However, very few life-size statues were found intact, as after the Classical age it became customary to detach the heads of Greek statues in order to create head-portraits. In fact, with few exceptions of statues found intact but in a smaller scale, this class of Greek statues in Sicily is represented just by heads without matching bodies, and headless bodies. A unique case is that of the "Biscari head" kept at the Museo Civico "Castello Ursino" of Catania and of the torso from Leontini in display at the Regional Archaeological Museum "Paolo Orsi" of Siracusa, both made of marble, dated between the end of 6^{th} - beginning of 5^{th} century BC and almost unanimously believed to be part of the same life-size kouros [PS09]. The head was part of the private collection of Ignazio Paternó Castello, 5^{th} Prince of Biscari (1719-1786), the founding figure of early archaeological research and antiquarianism in 18^{th} century Sicily [Paf09]. The head, also known as "Biscari head", retrieved in the site of the Greek city of Leontinoi, was exhibited for a long time in the Hall of Marbles of the Museum of Palazzo Biscari alla Marina (Fig. 1) before being incorporated in the main collection of the Museo Civico "Castello Ursino" of Catania [Lib30, Lib37]. In a rare picture taken around 1938 from the archive of Fratelli Alinari (Fig. 2), the head appears set on gypsum base attached to a wooden pedestal, which was later removed.

Figure 1: *Catania, Museum of Palazzo Biscari alla Marina, Hall of marbles [Paf09].*

The torso (Fig. 3) was accidentally found in the country right outside the area of the ancient colony of Leontinoi and purchased in 1904 for 1,000 liras by Paolo Orsi from the Marquis of Castelluccio, who was another famous collector of antiquities. Due to the approximate context of provenance, the statue should have had funerary functions. As separated artefacts the two pieces were subject of several studies aimed to define their style, chronology and eventually also their provenance. The consensus of the scholars attributed

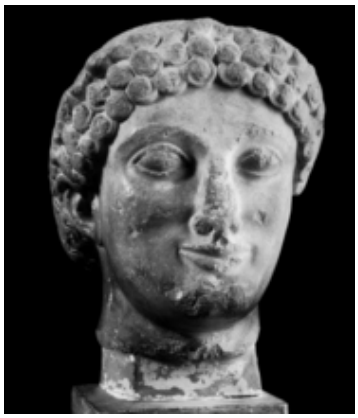

Figure 2: *The Biscari head (Archivio Fratelli Alinari, Firenze, 1938).*

them to a Sicilian workshop influenced by Attic-Ionic style, possible located in the area under the control of the Chalcidians, as Leontinoi was, where raw blocks of marble regularly arrived from the Aegean [BL12]. The closest comparisons that can be drawn for the head are the Rayet head of the Copenhagen Museum (Fig. 4), the Kouros of Aristodikos from Attica (Fig. 5) and the so called Theseus of a group from the temple of Apollo at Eretria (Fig. 6), all artefacts ranging between 520 and 500 BC [PS09].

Figure 3: *The torso from Leontinoi (photo authors).*

The first scholar who suggested a possible association between the head and the torso was Guido Libertini in the 30's. He produced a gypsum cast of the head in order to try it on the torso to verify his hypothesis. Although a missing part of the neck did not allow for a perfect match, the volumetric correspondence together with the stylistic analogies were enough to support the idea that the two pieces were once a life-size kouros from Leontini. Unfortunately no documentation has been recovered for this experiment. Many decades after, Gino Vinicio Gentili reappraising the problem of the association of the two pieces published a photofit (Fig. 7), where he matched the photographs of the head and the torso [Gen02]. This further confirmation of Libertini's hypothesis was published in a

Figure 4: *The Rayet head [Ric60].*

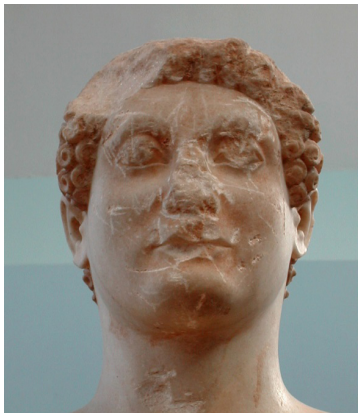

Figure 5: *The Kouros of Aristodikos [Ric60].*

scientific paper with a very limited distribution. Again, the general public missed the remarkable discovery of the first intact Sicilian kouros.

In order to go beyond the exercises of Libertini and Gentile and to provide the final proof of the compatibility of the two pieces as part of the same statue, a reconstructive study has been carried out based on the 3D scanning and virtual restoration of the kouros of Leontinoi.

3. Techniques and devices

In recent years, 3D scanning has played a relevant role in many research domains including medicine, architecture, industrial applications and, last but not least, Cultural Heritage [ACP*10, GMS*10, STBB, STG*]. Thanks to miniaturization and integration of the electronic and optical components, 3D scanners today are compact and flexible, with advanced Image Processing and Computer Vision algorithms that guarantee a high quality digital 3D geometry. The 3D scanners are able to estimate depth measurements, in order to acquire the geometrical structure of a real world object and produce a 3D digital version. These devices can be classified into several categories which depend on a specific feature.

Figure 6: *The Group of Theseus and Antiope from the Temple of Apollo at Eretria [Ric60].*

Figure 7: *Photofit of the head and the torso [Gen02].*

One of the main important feature concerns the emission of a signal to perform the acquisition. In this context we can distinguish active scanners, which need to introduce a particular electromagnetic signal for depth estimation, from the passive ones, which are able to acquire the 3D information by not emitting their own signal. Another aspect used to classify 3D scanners is the mobility. In the last few years, many portable scanners have been developed, among them hand-held devices, which are small, fast and relatively cheap. However, they are usually less accurate than the fixed ones due the different acquisition technology and hardware limitations.

3.1. Structure Sensor

Structure sensor [BBF15] (Fig. 8) is an active scanner which use the structured light for the 3D estimation quite popular among archaeologists. Specifically, it projects an infrared points grid whose deformation provides depth information. The scanner does not work well with sunlight, because the infrared light that the sun radiates, interferes with the grid pattern emitted by the scanner. Hence, it is preferable to use it in indoor environment.

The sensor is designed for developers, indeed the manufacturer

Figure 8: *Structure sensor clipped onto an iPad.*

provides its own SDK and maintains the library OpenNI 2. The scanner guarantees a maximum resolution of 1.0*mm* and a max accuracy of 0.5*mm*. However, the accuracy critically falls when the distance between the sensor and the scanned object is increased. On the other hand, the resolution decreases when the volume to scan becomes larger. This device can run in three different modes. Firstly, the sensors can be clipped on an iPad to exploit its hardware and software to acquire and export the 3D mesh of the acquired object. Although this modality gives the maximum mobility, it has a big drawback: the acquired 3D model can be exported through email only, and it is heavenly decimated. Hence, the exported model results in a low resolution mesh. However, this obstacle can be bypassed by connecting the iPad to a common personal computer through adequate hardware and software. The link between the iPad and PC is established thanks to a Wi-Fi connection and the software Skanect. It is important that both the devices (sensor and PC) are connected to the same access point. In this mode, the Structure sensor captures points and send them in real time to the connected PC for the processing and mesh creation. The greater hardware resources of a PC allows it to perform higher quality scans. Moreover, the mesh is directly stored in the PC. Finally, the sensor can be directly connected to a PC USB port through a particular cable provided by the sensor developers. This strategy ensures a higher frame rate throughout than a Wi-Fi network. The main problem with using Structure sensor in this modality is related to texture acquisition. The sensor has no RGB camera, hence if the operator decides to capture color information, it is mandatory to employ an iPad camera. This means that in the first and second mode only the texture can be acquired. The Structure sensor is relatively affordable and very fast. Moreover, user mobility is very high, by allowing the operator to turn around the artefacts and scan them entirely in a single run. Acquisition details and other information on the study case will be provide in the following sections. The hand-held scanner Structure sensor has been employed to acquire 3D models of two artefacts located in different museums: the head at Catania and the torso in Siracusa. Although the scanner is not able to represent fine details (max 0.5*mm*), its resolution is high enough to perform a digital alignments of the scanned objects.

4. Acquisition and data processing

The acquisition was carried out with extreme care in order to properly capture the many anatomical details of the two pieces (Figs. 9 - 10). The scanning was performed using the Structure sensor connected through Wi-Fi to Skanect in Uplink mode. The scan volume was set to $0.6m^3$ for the head and to $1.2m^3$ for the torso (Figs. 11 - 12).

Figure 9: *Details of anatomical features of the kouros.*

Figure 10: *Details of anatomical features of the torso.*

Both the artefacts are placed on a pedestal; in particular the head is fixed in the base onto a metal support. After digital acquisition the meshes were pre-processed deleting the vertices extraneous to the ones of the artefacts. The pedestals were cropped out from the acquired models. Then these 3D models were manipulated with two popular software among archaeologists. Meshlab [CCC*08] was employed in order to refine the models (Figs. 13 - 14) and after the process of gap filling and polishing the results turned out to be rather satisfying (Figs. 15 - 16).

In Meshlab, it was possible to take digital measures of the head and the neck is order to verify an eventual dimensional compatibility. As shown in Fig. 17 and Fig. 18, dimensions of the lower part of the neck of the head are 12.67×13.67 cm, while those of the upper part of the neck of the torso are 16.50×13.27 cm. Such

Figure 11: *Acquisition of the head at the museum of Catania.*

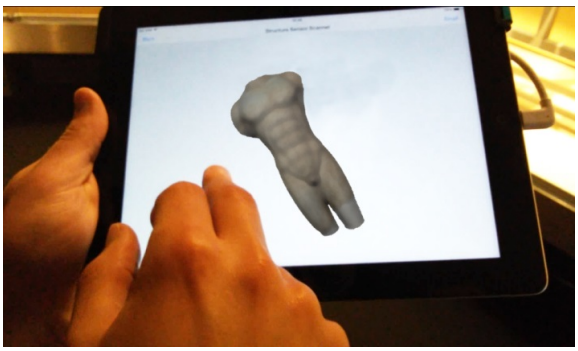

Figure 12: *Acquisition of the torso at the museum of Siracusa.*

dimensions, including a possible physical decay of the edges, informs us about a likely dimensional compatibility between the two pieces.

Furthermore, comparing the height of the head with the preserved height of the torso (Fig. 19) it emerges clearly a size matching between them.

Subsequently the models were imported into Blender [DPGIL11], in that virtual environment, the head and torso of the Kouros have been manually aligned because the technical and archaeological analysis have shown a missing part of the neck, obtaining the results showed in Figs. 20, 21, 22.

5. Discussion

5.1. Conclusions

The research presented in this paper has clearly demonstrated that the hypothesis suggested in the first place by Libertini was correct. The two pieces are certainly part of the same statue, as they did not just share the same stylistic features, but they are also compatible in terms of volumetry. The virtual reassembly has in fact added a further level of information which was not present in the photofit produced by Gentili, the readability of which was also improved with an algorithm [BCV06](Fig. 23. The statue seems very proportionate and the head, even in absence of a perfect match due to the

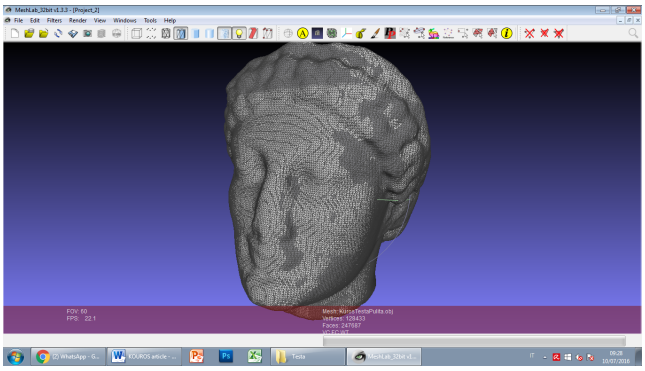

Figure 13: *Processing on the 3D model of the head in Meshlab.*

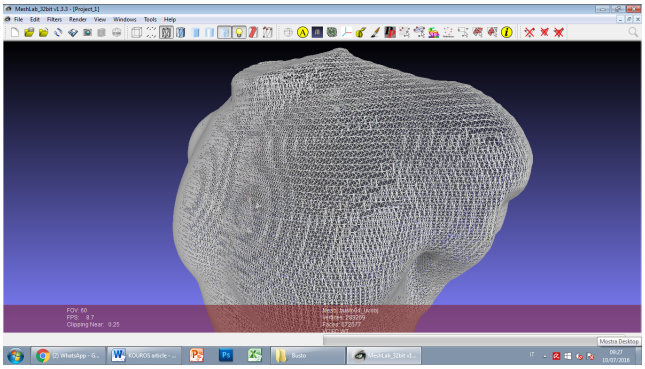

Figure 14: *Processing on the 3D model of the torso in Meshlab.*

Figure 15: *Textured 3D model of the head.*

Figure 16: *Textured 3D model of the torso.*

lack of a segment of the neck, perfectly fits to the body. A simple exercise of virtual restoration has given back to the community of scholars the first realistic representation of the kouros of Leontinoi, the first life-size statue of Archaic kouros from Greek Sicily. How would it be possible then to share with the public this remarkable discovery? How will the reputation of the two artefacts be improved by that discovery? Due to strict management policies, none of the two museums will surrender one of the pieces to the other in order to recombine the pieces and allow just one of the two institutions have it in display. It implies that the general public will never know about the Kouros of Leontinoi and will never have the chance to see it.

In response to this scenario, a web platform has been properly arranged in order to share in a simple and effective way the results of this research (http://yoda.dmi.unict.it/kourosSTAG/) [AAA*](Fig. 24).

The aim of this tool is to provide a high quality visualization of the combined 3D models, linked with related metadata in order to provide an accurate archaeological and historical context to the artefacts [STG*, MGL*]. Another advantage of the use of this web platform is the opportunity to upgrade the versions of the 3D models to monitor the conditions of the artefacts and to involve the community of world wide web users in the discussion [STBB, BCV06, ST]. A prototype of the system has been developed with Unity engine, version 5.0. Unity is a development platform with an integrated graphic game engine created by Unity Technologies. Unity is mainly used to produce videogames and entertainment products for different platform such as PC, consoles, and mobile devices, and it allows for the management of 3D models and other 3D content such as lights, pictures and videos. Unity 5.0 has an integrated development environment (IDE) named Mono Develop, aimed to develop computer codes in two programming languages, JavaScript and C#, the latter used for the present work. The user of the web platform will be able to interact with the 3D model of the Kouros of Leontinoi simply by using the mouse. The software provides two main views, Shaded and Textured. In the first view the 3D model will appear without material or texture and just the geometric data will be available, in order to focus on the analysis of certain anatomical details which can be obscured in the textured view (such as missing parts, gaps, tools' marks) A further phase of the current research will include the 3D printing of the two models, possibly in scale 1:1, in order to create some physical replicas of the Kouros of Leontinoi to be displayed in the Museo Civico "Castello Ursino" of Catania and the Archaeological Museum "Paolo Orsi" of Siracusa, and also in the Archaeological Museum of Lentini, where the majority of the artefacts from the ancient Leontinoi are exhibited. This research has elucidated how 3D

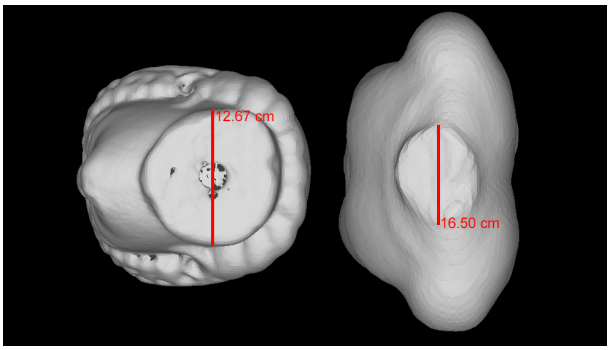

Figure 17: *Phases of digital measuring with Meshlab, dimensions of the edges.*

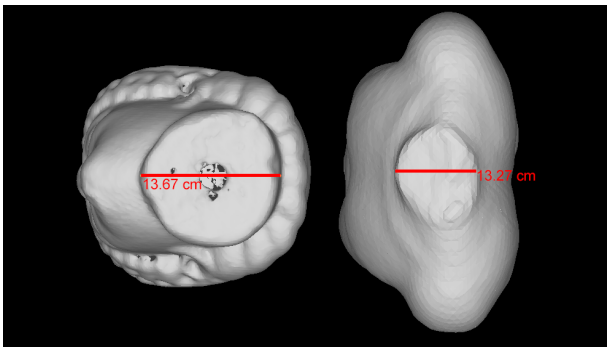

Figure 18: *Phases of digital measuring with Meshlab, dimensions of the edges.*

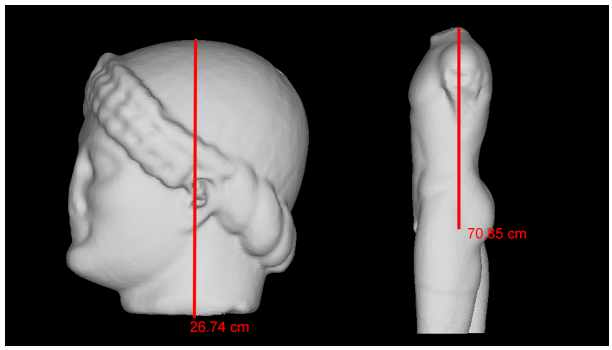

Figure 19: *Phases of digital measuring with Meshlab, heights of the pieces.*

Figure 20: *Manual alignment of the 3D models of the head and the torso in Blender.*

scanning and virtual restoration can contribute to the improvement of museum policies in the field of public outreach, showing how a case of limited cognitive accessibility, represented by the state of this statue irremediably divided in pieces between two museums, can become the public's path to virtual discovery of a new masterpiece of Greek sculpture.

5.2. Acknowledgment

The authors are grateful to curators of the Archaeological Museum of Siracusa for the collaboration and to the director of the Museo Civico "Castello Ursino" for the authorization to carry out the 3D scanning of the Biscari head.

Figure 21: *Manual alignment of the 3D models of the head and the torso in Blender.*

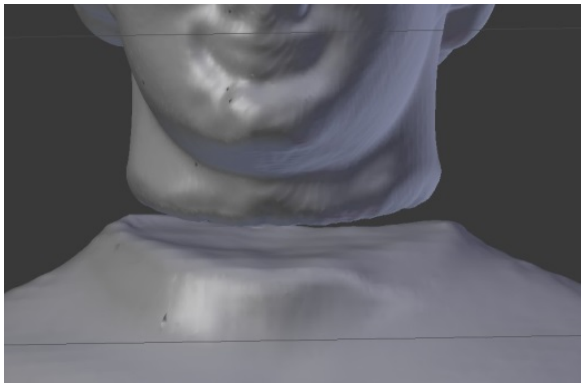

Figure 22: *Manual alignment of the 3D models of the head and the torso in Blender.*

Figure 23: *Comparison between the photfit produce by Gentili and the virtual restoration of the Kouros of Leontinoi.*

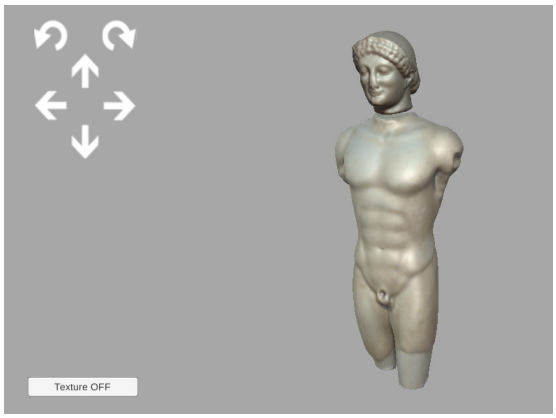

Figure 24: *Screenshot of the web platform for the virtual interaction with the Kouros of Leontinoi.*

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