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A 3D Digital Approach to Study, Analyse and (Re)Interpret Cultural Heritage:
the Case Study of Ayia Irini (Cyprus and Sweden)

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Abstract: This paper focuses on the on-going doctoral research of the writer. Specifically, the topic of this article is on the metho-dology, the theoretical approach and the first steps of the research. The general aim is the contribution of 3D documentation and the 3D digital approach to the stylistic and typological study of archaeological collections. The study is applied to the collection of the Ayia Irini archaeological excavation (Cyprus). The site was excavated and studied at the beginning of the 20th century by a Swedish archaeological mission and the collection was divided between Cyprus and Sweden. The scope, through the integration of digital technologies, is the three-dimensional documentation of the archaeological material for its (re)interpretation and its metric analysis and comparison. Particularly, the paper will focus on the pipeline and methodology developed for the choice of the sam-ple, its digital acquisition and the analysis of the statues.

Keywords: 3D documentation, 3D digital approach, Digital analysis, Archaeological collections.

Introduction

The paper here presented is about the first steps of the on-going doctoral research of the writer, the methodology and the theoretical approach developed for the study and analysis of archaeological collections through the use of digital technologies.

1 Research aims

The idea at the base of this research comes from the necessity to answer fundamental questions in the field of Archaeology and Digital Cultural Heritage studies, in particular to solve issues about the analysis, interpretation, and re-interpretation of archaeological materials.

- How to geometrically and metrically analyse and compare archaeological artefacts of an archaeological collection in order to interpret and extract stylistic and typological information for their interpretation?

- How digital technologies can help the documentation in order not to lose any information of archaeological materials?

- How technologies can help archaeologists to give new interpretations about past studies and support current ones?

Three-dimensionality has been more and more used in the field of computer science applied to archaeology: at today it is possible to see different applications about diachronic reconstruction of different occupations of a site, virtual reality systems or modelling and animation of artefacts. Within this general frame, the on-going doctoral research aims at the contribution and use of 3D documentation for the analysis of archaeological artefacts.

The major scope, through the integration of digital technologies, is the documentation of a sample of the Ayia Irini archaeological collection, its (re)interpretation and digital analysis. The specific aim is in fact to understand how these statues were made, from a technical perspective, to identify modalities of creation, workshop/artisan(s) and so forth. Such an analysis is performed through a detailed 3D documentation of a selected sample of figurines.[1]

The topic of this paper focuses on the methodology, the theoretical approach and the first results of the research, applied to the collection documentation. Specifically, this paper focuses on the pipeline and methodology developed for the choice of the sample, its digital acquisition and the analysis of the statues on the base of a standardized study of their three-dimensional elements.

2 The case study of Ayia Irini

2.1 The archaeological context

The ancient sanctuary of Ayia Irini is located near the current village of Ayia Irini, in the Morphou district in northwest Cyprus. The sanctuary was discovered and excavated by a Swedish archaeological mission in 1929. Fig. 1

The importance of this rural open-air sanctuary lies in the fact that the worship was inaugurated in Late Cypriot III and survived until the last quarter of the Cypro-Archaic II period, furnishing the only example of a complete archaeological sequence of *strata*, proving continuity of worship from the 11th to 6th century BC Following a terrible flood around 500 BC, the *temenos* was abandoned and reused again in the 1st century BC (Gjerstad 1948).

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[1] The geometrical 3D representation will allow us to perform the extraction of the statues' elements as well as their characterization.

FIG. 1. THE SANCTUARY OF AYIA IRINI AT THE TIME OF THE DISCOVERY.

2.2 The Collection(s)

The sanctuary at Ayia Irini is famous for its large number of terracotta figurines (some of them larger than life size) that were found *in situ* positioned around the altar of the sanctuary. These figurines, *ex votos* offered most probably to a male god, number to approximately 2000. They are animals, bulls, minotaurs, chariots and male figures representing warriors and priests with helmets or conical caps and different attributes (votive offerings, arms, musical instruments) (Gjerstad 1933; Gjerstad 1948).

With the British Government's permission, the findings were divided between Sweden and Cyprus. More than half of the figurines were transferred to the Medelhavsmuseet in Stockholm (Sweden) (Karageorghis 2003), representing the largest and most important collections of Cypriot antiquities in the world outside Cyprus, while the rest is in the Cyprus museum of Nicosia (Cyprus) (Fisher and Keneberg 2003). A small number of items is conserved at the Historical Museum of Lund University (Sweden), brought there by E. Gjerstad, the archaeologist responsible for the Swedish Excavation mission in Cyprus, during his professorship at Lund University during the 1940s.[2]

3 The methodology

The methodology developed for the research is based on the following main phases:

- Gathering of historical and archaeological information about the collection

- Data sampling of the collection(s)

- 3D data capture and post-processing of the samples

- 3D analyses and comparisons of the digital artefacts

3.1 Data gathering

A gathering of high-quality data is really important to set up a verifiable and reliable plan of work and the successive study and analysis of the material, the subject of our research. The gathering consists of three different steps.

The first one is the collection of all the texts, literature, ancient sources and studies about our archaeological context and collection, as well as information about case studies with temporal, geographical or morphological similarities. In case of lack of data, the comparisons with similar cases help us to fill up the possible gaps in our documentation and give the possibility to draw some conclusions (Vassallo *et al.* 2006).

The second step is instead constituted of the direct observation of the artefacts and the capacity of the archaeologists to see the elements and the details of what they are studying. Also this activity helps to extract ideas, hypotheses and preliminary interpretations.

This kind of data gathering allows us to proceed in a further direction in the development of the methodology, helping us in the successive analysis and comparison phases. The step consists of the development of a framework (an archive) for the description of the object (both real and digital) and their characteristics, and according to a structured schema useful to preserve all the information.

The other step of the methodology is constituted of the use of digital technologies for acquiring another kind of data that

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[2]   Since the artefacts are currently placed in different countries and museums, the use of the methodology developed for the research should help in better understanding the original spatial-metric relations between the different components of this collection.

Fig. 2. The Ayia Irini collection(s).

is not possible for an archaeologist to get simply with the direct observation. This in fact permits to geometrically and metrically obtain the shape, dimensions and texture details otherwise not visible with a naked eye or difficultly acquirable with a simple manual measurement.

3.2 Data sampling, digital technologies integration, data acquisition and post-process

3D documentation is a well-known approach to research on documenting, analysing and preserving archaeological data. The 3D model obtained by the use of a single or by the integration of different technologies and methodologies is a real database that allows us to extrapolate morphological and geometric information with a particularly high resolution (Georgiadis et al. 2009).[3]

A reliable and comprehensive metric description is a key element in every knowledge process: the simulation of the space through measures reduces the complexity of reality to a unique model. In particular, photogrammetry (e.g. capture from motion, image based modelling, etc.) and 3D scanning systems allow to realistically replicate the 3D geometry and texture of archaeological assets.

An important part of the methodology development consists of the data sampling of the artefacts to be three-dimensionally acquired. The choice of the dataset is representative of the material found in the archaeological site of Ayia Irini and from the museums where it is stored (Stockholm, Lund and Nicosia museums). The data sampling methodology is based mainly on typological and stylistic characteristics.

The first 3D acquisition test was carried out on the collection conserved at the Historical Museum of Lund University. It consists of 15 items belonging to the Ayia Irini collection, but it was decided to digitize 13. The choice is based only on terracottas that represent standing figurines, in order to standardize the kind of shapes chosen for future analyses and comparisons. Therefore statues representing groups (chariot groups) and animals have been deliberately excluded by the three-dimensional data acquisition campaign.

In the sample has been included and three-dimensionally acquired also 3 items that are a bit bigger in size respect to the rest of the dataset. The choice of the sampled items is focussed
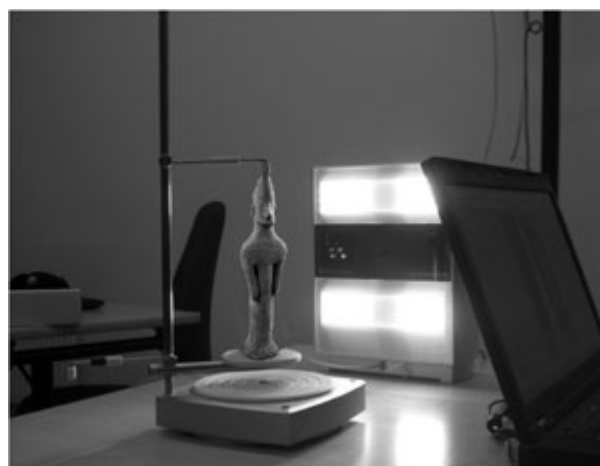

Fig. 3. Data acquisition of a terracotta with NextEngine 3D Desktop laser scanner.

on figurines around 20cm high in order to verify and analyse afterwards the presence of ratio, production process, etc. during the comparison of the 3D geometries; to extract possible production elements and to see if any standardizations in the production itself exist. The data acquisition of these 3 more items would be useful for the confrontation and comparison in the extraction of standardization elements in the figurine's creation.

Due to the size of the sample, the material, the shape, and surface characteristics of the artefacts, the geometry of the statues have been digitally acquired with a NextEngine 3D Desktop laser scanner. Fig. 3

Moreover, in order to guarantee also a high definition quality texture, for the preservation of the visual characteristics (colours, material characteristics, micro elements, etc.), the statues have been digitized through an image-based modelling technique (post-processed with Agisoft PhotoScan)[4] (Verhoeven 2011).

After this, the outcomes are integrated, in order to have more detailed models both for their geometry and for their texture (not only for the scope of the 3D analysis, but also for the

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3 The study focuses also on the establishment of the pipeline for the 3D acquisition and integration of different digital techniques for the scope of the current research (Bernardini and Rushmeier 2002).

4 In some cases where the details are not easily visible and therefore acquirable by the laser scanner, this technique provides also greater details of the geometry.
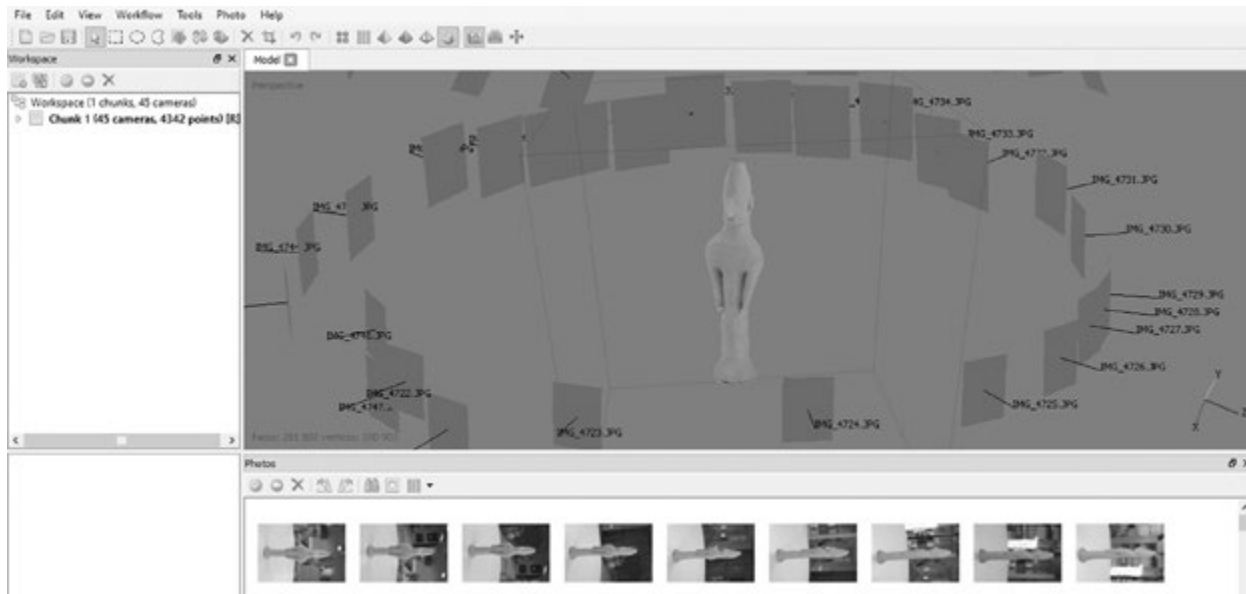
Fig. 4. Image based modelling post-process with Agisoft PhotoScan.

visualization purposes in the possible development of the doctoral project in the future) (Beraldin 2004; Remondino and El-Hakim 2006; Gonizzi Barsanti *et al*. 2013).

3.3 3D analysis and comparisons

A significant problem in archaeology is the difficulty in comparing many artefacts stylistically and geometrically, requiring this activity substantial physical information. Relating one artefact to another is an integral part of discovering its role, age, artisan, community, etc.

3D gives exactly the possibility of an interactive or automatic quantitative and qualitative comparison (Hermon *et al*. 2010). The use of 3D models allows studying in a detailed and measurable way the elements of the artefacts and it permits a visualization and measurable comparison that can be easily at disposal of the scholars for analysis.

As previously explained, this contribution is a preliminary dissemination of the on-going doctoral research. This means that the 3D analysis is under processing, and still the work of 3D acquisition has to be concluded for the different parts of the collection divided between the different museums already mentioned.

In general, the geometrical representation of measurable 3D models (with millimetric precision), will allow to perform the extraction of the statues' elements as well as their characterization. Through that it will be possible to identify technical features such as the manufacture, use of standards, guidelines or rules (e.g. ratio between the parts, standards or fixed dimensions) in the production of these artefacts or to identify the individual workshop's methodologies and techniques (or different workshops and/or artisan/s). The metrical comparison of the geometries will further help to identify the similarities and dissimilarities and therefore to

draw conclusions about the production of the material (see Fig. 6.).[5]

Currently the analysis is at its early initial stage and different tests are ongoing. 3D geometries and 3D features of the statuettes are firstly being compared in Meshlab: distances between the parts, lengths and widths are measured and stored in order to create a database of these measurements and consequently to run ratios and statistical analyses. A further analysis is planned by employing Geometric Morphometrics (GM) techniques in order to compare and analyse statistically the 3D forms of the sampled items.

4 Conclusions and future works

The 3D documentation provides an effective database of information that, beyond assuring the digital preservation of the material, is first of all a useful source for further studies and a reference for new knowledge extraction. In fact, digital data give the opportunity to perform multiple tests and analyses that, differently from the test on the real object, can be repeated many times and in a more detailed way (Moro *et al*. 2007), thanks to the possibility of replicating an object with the same exact dimensions, shape, size and texture of the real one (Athanasiou *et al*. 2013).

The research aims at the study and analysis of archaeological collections through the use of digital technologies and the application of a 3D digital approach, specifically to the case study of Ayia Irini's terracotta statues. For doing so, an important step is the development of a methodology that supports all the research pipeline: the choice of the sample, the assessment of the appropriate technologies to be used, the 3D data documentation, the post-process, the digital analysis and the extraction of the results.

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[5]   3D technology is used as an exploratory tool for data analysis and for catching relations between objects that are no longer in situ.
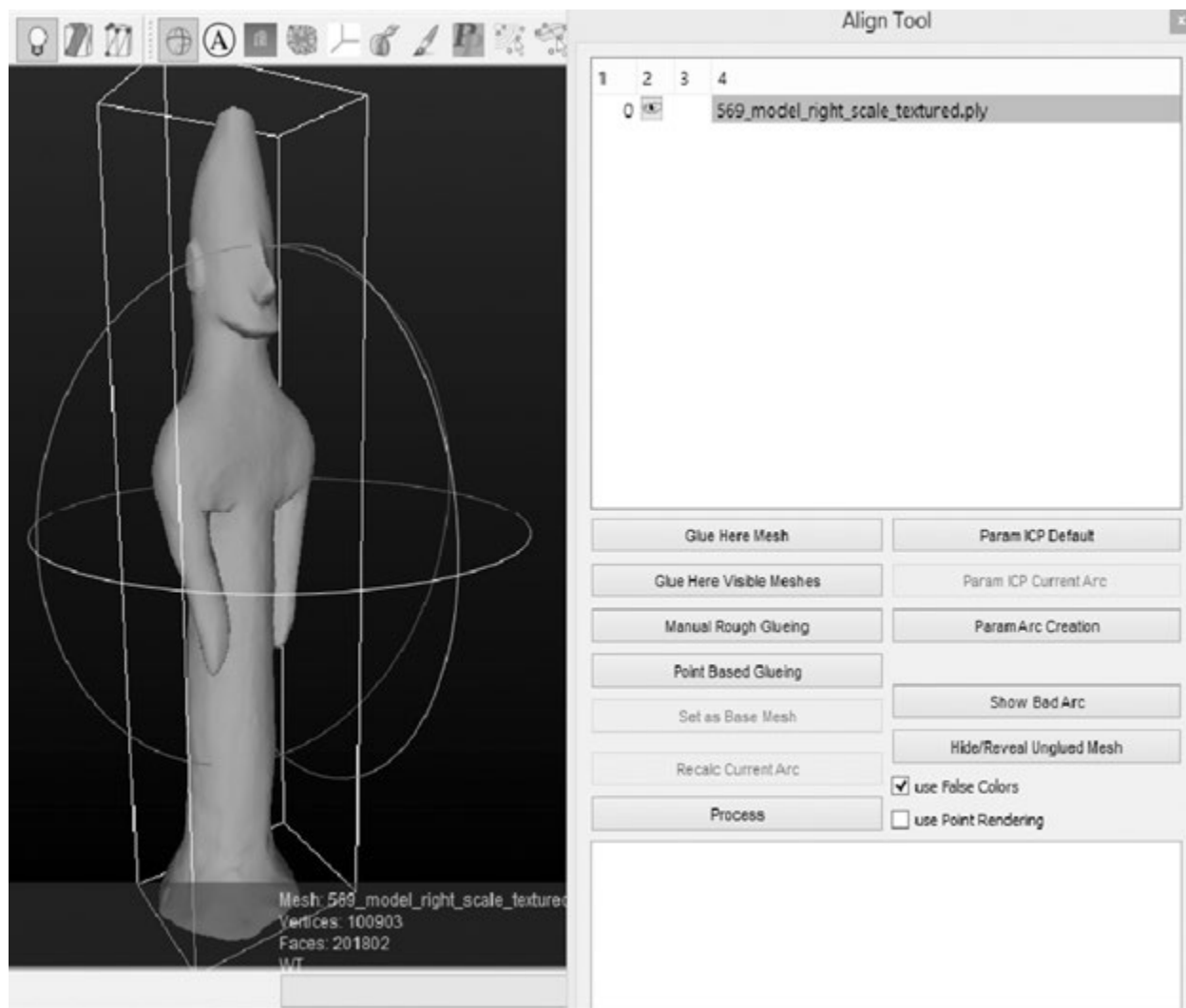
Fig. 5. Post-processing of the digital artefacts with Meshlab (Cignoni *et al.* 2008).

Fig. 6. Extraction and digital comparison of the elements from Ayia Irini's 3D models.

The methodology has been developed and successfully tested on the first sample of terracottas, conserved at the Lund University Museum. The current work is focussed on the sampling of the other part of the collection for the 3D digital data acquisition and analysis. The methodology and the pipeline could be further implemented and adjusted according to the development of the research.

The next step of the research is therefore the digital documentation of the remaining terracotta statues and after this phase will start the analysis and the comparisons between all the 3D models, in order to detect similarities and dissimilarities for the identification of rules, ratio or specific elements that can give us clues and/or confirmation about their production (e.g. use of moulds for some parts of the artefacts, serial production, one/many recognizable hands, etc.).

At the moment the research is planned only on the analysis and comparison among the 3D replicas of the Ayia Irini collection. A possible further useful development could involve the 3D digitization and analysis of some statues from Cyprus and chronologically similar. This could be useful to understand their affinity with similar statues from other archaeological

sites and to have a brighter and larger view, since based on measurable elements, about the coroplastic production in Cyprus (Karageorghis 1993).

The research will possibly further include the positioning of the statues' 3D models in a 3D GIS environment of the sanctuary (Dell'Unto 2014), reconstructed on the base of the documentation, plans and drawings published by the Swedish archaeological expedition, in order to have a unified access of the collection and a holistic vision of the archaeological discovery.

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