

Digitization, Restoration and Visualization of Terracotta Figurines from the ‘House of Orpheus’, Nea Paphos, Cyprus

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Abstract. The terracotta figurines from the so-called ‘House of Orpheus’ in Nea Paphos, Cyprus, and in particular the terracotta figurines excavated between 1982-1992, form part of a significant material assemblage that spans in time from Hellenistic to Roman times. These high quality terracotta figurines fall within the mainstream of Cypriot art and its associated ancient technological and cultural systems. The research project presented here, aims at a systematic assessment of this assemblage employing stylistic, analytical, computational and theoretical methods of study. Emphasis is given to the digitization process that involves 3D scanning of items of interest; and the subsequent processing that aims to reconstruct and visualize specific fragmented specimens in their anticipated full shape and colour. Also presented are our plans for developing interactive applications that utilize 3D models of the specimens.

Keywords: Terracotta figurines, 3D scanning, visualization, interactive tools.

1 Introduction

Terracotta figurines embody ancient tangible and intangible cultural evidence and meanings. Cyprus has a strong coroplastic tradition with a prolific production in many types and sizes dating back to the Chalcolithic period (ca. 3900-2500 BC). The multifaceted significance of Cypriot terracottas has been acknowledged by the large corpus of published data. This addresses a series of interlinked issues, related to their typological, stylistic and chronological classification, the technology and techniques employed in their manufacture, their provenance, the mode of their production, the scale of their distribution, and their role as cultural artifacts in differing social contexts. Special reference should be made first to the corpora of the ‘Coroplastic Art of Ancient Cyprus’ by Karageorghis [1] (dealing with earlier periods), secondly to the proceedings, edited by Vandenaebale and Laffineur, of the only conference ever dedicated to Cypriot terracottas [2], (also very focused on earlier terracottas) and, finally, to the recent work of Kilikoglou *et al.* [3], who applied fabric analysis for the

study of provenance. It should be noted, however, that all the above, as well as other detailed studies [4, 5, 6], because of the nature of the excavations and of the published evidence, usually remain bound to ritual and burial contexts; in other words, we still need to understand the domestic function of terracotta figurines in ancient Cyprus.

Despite the substantial contemporary studies on earlier Cypriot terracotta figurines, the Hellenistic (ca. 310-30 BC) and Roman (ca. 30 BC-330 AD) ones remain highly neglected and detached from recent theoretical and scientific developments. They usually appear, separated from their depositional context, in museum catalogues; or, due to their inexpensive nature and ‘inferior’ position in relation to sculpture, selectively in excavation reports (e.g. [7]). The only comprehensive and detailed study of Hellenistic and early Roman figurines is that by Queyrell on the finds from Amathous [8]. While this volume represents a superb and paradigmatic case-study, it remains close to ‘traditional’ approaches to style, chronology and iconography.

Recent theoretical and scientific developments in the study of Hellenistic and Roman terracotta figurines from other Mediterranean areas have clearly shown that “researchers can now have a much greater grasp of the role played by terracotta figurines in the religious, social, domestic, economic, and political spheres of Greek and Roman life” [9]. The ‘House of Orpheus’ remains one of the most important excavated sites of Hellenistic and Roman Cyprus [10], where a significant number (about 300 fragments so far) of terracotta figurines has been found. The fragments come from terracotta figurines of varying sizes, ranging from about 10 to 25 cm in height. Quite often the figurines (or joining fragments of) are preserved in good condition, and identification of what is represented is therefore possible.

The aim of our project is to perform a systematic assessment of the assemblage of terracotta figurines found during excavation at the ‘House of Orpheus’ in Nea Paphos (see figure 1), employing stylistic, analytical, computational and theoretical methods of study. Moving beyond the individual analytical datasets at a micro-regional level, the project aims at providing a reference collection for future research, setting the scene for further systematic study of Hellenistic and Roman terracotta figurines from Cyprus and the wider Mediterranean world. In addition, the project aims to raise public interest in this type of findings, through the development of novel computer applications in relation to these terracotta figurines.

In this paper we outline the main aims of the project, giving emphasis on the digitization process that involves 3D scanning of the items of interest, and the subsequent processing of the resulting 3D models. This is the first time that archaeological and stylistic analyses in combination with computational methods are applied to the study of terracotta figurines of the period. It is anticipated that the outcomes of the project will benefit archaeologists, artists and museum visitors.

2 Project Overview

The main aims of the project are:

- The design of a database providing data related to the terracotta figurines in question. The database will allow the cataloguing and processing of excavated finds leading to the production of stratigraphic, spatial, and statistical results.

- The typological, stylistic and iconographic analysis of the figurines. After a quantification of terracotta figurines (almost intact, broken and fragmentary), we aim at identifying their iconographic types and chronologies employing art-historical examinations of style and iconography. This kind of analysis can be achieved more easily for the complete or almost intact figurines; however, the analysis of fabrics (see below) can probably help us identify the chronology of some of the more fragmentary examples.
- The compositional characterization of terracotta figurine fabrics, slips, and pigments employing chemical methods of analysis, such as Wavelength-Dispersive X-ray Fluorescence and Neutron Activation Analysis. The results of these analyses will be compared to fabrics, slips and pigments from Cyprus, which were collected and analyzed under similar techniques by our partners.
- The use of statistical analyses, including principal components analysis and cluster analysis, for testing the correspondence between the analytical datasets. These classificatory and reduction statistical techniques will be used for defining both groupings among the compositional data, and for clustering probable parts of a single figurine. In addition, through these techniques, graphical representations of relationships between the samples will be displayed.
- The documentation (through bibliographic description, photography and video recording that will be archived and used for a public exhibition) of the techniques employed for the manufacture of the terracotta figurines, and their evaluation by means of experimental work. This work includes the selection of raw materials for the production of the body fabric and decorative slips, as well as firing and post-firing treatments. The reproduction activities aim at the more detailed evaluation of individual stages of the production sequence and the technologically authentic replication of some terracotta figurines.
- The study of the inscriptions incised on some of the figurines. By matching the fragmentary pieces of the figurines and by employing basic epigraphic analysis we intend to identify the significance of these inscriptions.
- The use of computational methods for digital restoration of fragmented specimens and the development of dedicated applications for visualizing and exploring/interacting with the digitized specimens.
- The contextualization of the figurines within their individual depositional intra-site context, as well as their broader socio-cultural and socio-political Cypriot and Mediterranean contexts, using a range of comparative studies and social theory. Figurines are seen as active and symbolic elements in their depositional and social contexts. Comparative studies with other Cypriot sites (e.g. [8]) and other areas of the Mediterranean (e.g. [11]), as well as the application of a range of social theory and spatial analysis related to 'agency', 'objectification processes', 'social technology', 'material-culture-as-text' and 'embodiment', will help us clarify the levels of human interactions, cultural transformations, the messages the figurines might convey and their dialectic with people.

In order to accomplish the aforementioned tasks, this two-year project is divided into five main work-packages: 1. Creation of an electronic database where all information

(site co-ordinates, identification, breakage, dimensions, clay, joins to other fragments, chronology) related to each object is stored; 2. Stylistic analysis of terracotta figurines. This aims to establish the typo-chronological evolution of the terracotta figurines and their socio-symbolic dimensions within a broader Cypriot and Mediterranean context; 3. Intra-site spatial analysis of terracotta figurines producing mapped distributions according to a range of variables (i.e. chronology, identification, joins and function); 4. Analytical insight into the technology of the production and circulation of the figurines through physicochemical analysis and experimental work; 5. Digitization, visualization and restoration of almost complete and fragmented figurines.

In this paper we focus our attention on the work-package on "Digitization, Restoration and Visualization". It is worth mentioning that this research is still in the early stages of implementation, hence the work reported is still under development. Nonetheless, it is hoped that this multidisciplinary project will not only fill a lacuna in Cypriot coroplastic studies, but will also introduce recent scientific and theoretical developments to the study of terracotta figurines, acting as a paradigmatic case-study for figurines from other areas and periods. While the project can serve as an example for the examination of objects coming from a well-stratified context, at the same time it can solve long-standing problems for the understanding of un-stratified figurines found during looting or the antiquarian approaches of early explorations, which were primarily interested in the creation of art collections and neglected important aspects related to the archaeological context of the objects.

3 Digitization, Restoration and Visualization

The aim of this work-package is to use 3D scanning for generating 3D models of terracotta figurines. The resulting models will be used as the basis for creating moulds that will be used for the physical reproduction of selected figurines. Apart from the physical reproduction process we also aim to develop dedicated tools suitable for processing the resulting 3D models. The tools we plan to develop are divided into those involving the use of computational methods for processing the 3D models, and those involving the development of interactive tools that aim to engage museum visitors in exploring terracotta figurines. The paper also presents more details related to the work carried out and description of the work currently in progress.

3.1 Digitization

The digitization process is divided into two main tasks, namely the 3D scanning phase and the post-processing phase. The 3D scanning process was performed at the Paphos District Museum using the portable Z Corporation, ZScanner® 700CX (see Fig. 2). During the scanning process the 3D shape and texture of each item was recorded simultaneously.



Fig. 1. Examples of fragmented Cypriot terracotta figurines



Fig. 2. The scanning process

For each item, two scans showing its front and back were obtained. Each scan was then processed using the MeshLab software (<http://meshlab.sourceforge.net/>) so that artifacts that appear in each scan were removed and the processed scans showing two sides of the same object were stitched together so that complete 3D models of each item were produced. Examples of the 3D scan process and resulting integrated models are shown in Figures 3 and 4.



Fig. 3. Processing 3D scans: Raw 3D scans (left column), scans after noise removal (centre column) and a resulting model (right column)



Fig. 4. Examples of joined 3D models of fragmented terracotta figurines

The whole collection at the Paphos District Museum contains hundreds of terracotta figurine fragments. Among all the available fragments, archaeologists from our team selected the ones that are either deemed most important, or are expected to resolve important archaeological (and art-historical) issues if digitized. So far the digitization process has been completed for about 50 selected fragments. The overall time for digitizing and post-processing and generating complete 3D models is about 120 minutes.

3.2 Computational Processing

We are currently investigating the application of computational 3D image processing methods that will allow the virtual automatic restoration of fragmented items, the automatic grouping of the fragments and the application of primitive analysis in an attempt to identify repetitive structures in different fragments. The aforementioned prototype applications are being developed using MATLAB (www.mathworks.com).

3.2.1 Automated Virtual Restoration

The application of automated virtual restoration techniques capable of predicting the appearance of the missing parts of digitized fragments is among the aims of the project. Within this framework, information from the undamaged parts of an object is utilized in combination with other, relevant sources of information, in an attempt to re-create the appearance of the complete object. Fig. 5 shows preliminary results in applying automated restoration techniques for recreating the missing geometry of face-like structures. The method employed utilizes a 3D face style-specific deformable model as a basis for predicting the geometry of the missing facial regions [12]. The full implementation of this method will require the detailed study of similar specimens so that design rules and spatial constraints between facial features are not violated during the process of restoration. Similarly during the restoration of other types of objects (other than faces) we plan to employ design-style constraints in order to automate the process of virtual restoration. It is anticipated that due to the unique nature of the specimens, apart from the application of the automated restoration techniques, user intervention may be required so that the final restored 3D models are realistic. Trained 3D modellers will undertake the task of manual processing using dedicated 3D modelling tools such as MeshLab or Autodesk Maya. This effort requires close co-operation between the archaeologists and 3D modellers.

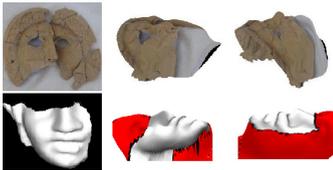


Fig. 5. Initial results showing restored fragment 3D shapes **Fig. 6.** Overlaying a mask on the face of a user

3.2.2 Fragment Grouping

In most cases only small fragments of terracotta figurines are available. Even though during registration all fragments thought to belong to the same item were grouped together, some fragments may actually be extraneous. Within this context, automatic classification and clustering methods will be employed in an attempt to verify that fragments belonging to the same item are grouped together correctly. For this purpose the use of shape and texture features related to the surface local structure [13], colour distribution, and other texture-related metrics [14] will be investigated.

3.2.3 Primitive Analysis

In many cases local details of terracotta fragments contain typical salient features that are encountered in multiple specimens. For this reason we plan to develop methods that will allow specialists to select primitive structures from a specific 3D model and search all available 3D models in order to locate other instances of the primitive in other fragments. The features in question will normally display typical structures

encountered in characteristic design patterns. For this purpose 3D template matching techniques [13] will be employed for identifying instances similar to the selected primitives with our database of 3D fragments.

3.3 Interactive Tools

The computational analysis tasks mentioned above, aim to provide tools for archaeologists and other specialists. As part of the project we also aim to produce interactive tools that will allow the general public to explore, visualize and obtain knowledge related to the terracotta fragments in question. A description of our plans is outlined below.

3.3.1 Virtual Museum

All artifacts will be displayed in a virtual museum framework where visitors will have the chance to visualize the items and obtain information about particular fragments and the overall theme of “The Terracotta Figurines from the ‘House of Orpheus’”. The virtual museum application will be developed using the UNITY3D (<http://unity3d.com/>) software and will allow the viewing on computer monitors.

3.3.2 Interactive Applications

Edutainment [15] is considered a very efficient way of disseminating information and knowledge, especially to the younger generation. Along these lines, apart from visualizing the data in a virtual environment, visitors will have the chance to interact with the virtual objects in a way that will stimulate the learning process. In order to accomplish this aim we plan to develop the following applications:

3D Puzzle: Users will have the ability to select and move, in a virtual space, terracotta fragments in an attempt to join them together in order to re-create the original artifact.

Augmented Reality-Based Experimentation on Using Terracotta Figurines: Some specimens among the digitized collection are items that have specific domestic uses. As part of this activity we aim to provide to users the ability to experiment in using different items in a way that mimics the intended usage of the artifacts. In this context, users will be required to study information relating to different items in order to figure out how to use them in an appropriate way. A preliminary example of this approach is shown on Fig. 6 where a mask is interactively fitted on the face of a user, thus demonstrating the intended use of masks.

4 Conclusions

We have presented a description of an on-going project that aims to investigate terracotta figurines from the ‘House of Orpheus’ at Nea Paphos, Cyprus. Special emphasis was given to the part of the project that deals with computation analysis of the specimens, and the development of interactive applications that will allow the general public to be acquainted with and obtain knowledge related to these terracotta figurines, but also to the history and culture of Hellenistic and Roman Cyprus. Within this scope, initial results and preliminary illustrations of on-going work were presented. Even though the overall project is still in the initial stages of

implementation, the results so far indicate that both the development of computational approaches and interactive tools can play a key role in supporting the analysis and exploration of the data available, both by specialists and the general public.

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