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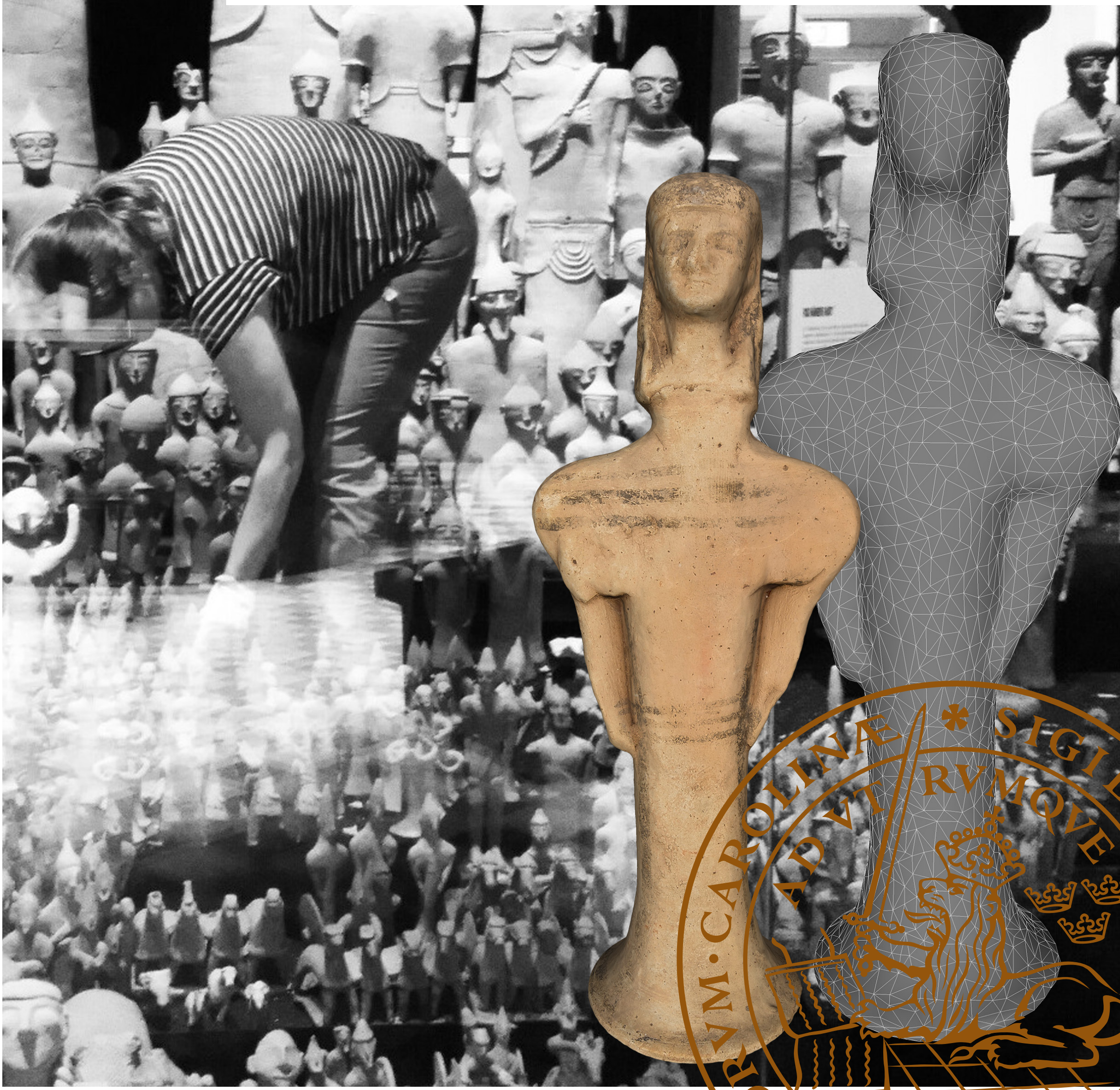

A 3D Digital Approach to the Stylistic and Typo-Technological Study of Small Figurines from Ayia Irini, Cyprus

Valentina Vassallo

DOCTORAL DISSERTATION

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Abstract
The thesis aims to develop a 3D digital approach to the stylistic and typo-technological study of coroplastic, focusing on small figurines. The case study to test the method is a sample of terracotta statuettes from an assemblage of approximately 2000 statues and figurines found at the beginning of the 20th century in a rural open-air sanctuary at Ayia Irini (Cyprus) by the archaeologists of the Swedish Cyprus Expedition. The excavators identified continuity of worship at the sanctuary from the Late Cypriot III (circa 1200 BC) to the end of the Cypro-Archaic II period (ca. 475 BC). They attributed the small figurines to the Cypro-Archaic I-II. Although the excavation was one of the first performed through the newly established stratigraphic method, the archaeologists studied the site and its material following a traditional, merely qualitative approach. The analysis of the published results identified a classification of the material with no-clear-cut criteria, and their overlap between types highlights ambiguities in creating groups and classes. Similarly, stratigraphic arguments and different opinions among archaeologists highlight the need for revising. Moreover, past legislation allowed the excavators to export half of the excavated antiquities, creating a dispersion of the assemblage. Today, the assemblage is still partly exhibited at the Cyprus Museum in Nicosia and in four different museums in Sweden. Such a setting prevents to study, analyse and interpret the assemblage holistically. This research proposes a 3D chaîne opératoire methodology to study the collection's small terracotta figurines, aiming to understand the context's function and social role as reflected by the classification obtained with the 3D digital approach. The integration proposed in this research of traditional archaeological studies, and computer-assisted investigation based on quantitative criteria, identified and defined with 3D measurements and analytical investigations, is adopted as a solution to the biases of a solely qualitative approach. The 3D geometric analysis of the figurines focuses on the objects' shape and components, mode of manufacture, level of expertise, specialisation or skills of the craftsman and production techniques. The analysis leads to the creation of classes of artefacts which allow archaeologists to formulate hypotheses on the production process, identify a common production (e.g., same hand, same workshop) and establish a relative chronological sequence. 3D reconstruction of the excavation's area contributes to the virtual re-unification of the assemblage for its holistic study, the relative chronological dating of the figurines and the interpretation of their social and ritual purposes. The results obtained from the selected sample prove the efficacy of the proposed 3D approach and support the expansion of the analysis to the whole assemblage, and possibly initiate quantitative and systematic studies on Cypriot coroplastic production.

Key words
Coroplastic, Figurines, Cypriot archaeology, 3D shape analysis, 3D GIS, Analytical investigation, Semantics

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To Luigi and Delia

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1.Introduction

This research shows that classification systems based on quantitative criteria, identified and defined with 3D measurements and analytical investigations, can enhance the archaeological and typo-technological interpretation in coroplastic studies.[1] The research stems from the consideration that, although in recent years there has been a substantial change in coroplastic studies (Les Carnets de l'ACoSt 2013-2020[2]), for too long, the field has relied on qualitative methods, where archaeologists define classes and types for interpretative or chronological aims through stylistic and aesthetic considerations. Such a qualitative-based approach is highly subjective, has limited repeatability, and relies too heavily on the researcher's training and knowledge. Moreover, the lack of consistent agreed-upon criteria for description and classification and the lack of quantitative attributes that would define one or another class make any comparative research difficult. Equally, when scholars consider quantitative information, those are often limited to general or approximate dimensions; for example, linear distances between points taken on three-dimensional artefacts are difficult to compare across several objects and impossible to replicate, even by the same person. The problem becomes more severe when the objects are scattered in various museums across countries, and their description and classification began decades ago within a traditional framework.

The directions taken in the last decades by a part of the archaeological community to better develop a discipline that focuses specifically on

[1] Coroplastic is the study of terracotta figurines: it takes its name from the word *koroplast*, used to identify the modeller of figurines in clay in ancient Greek.

[2] Les Carnets de l'ACoSt journal (https://journals.openedition.org/acost/) focuses on figurative objects made in clay from all periods and geographical provenance, promoting the development of coroplastic studies as a discipline *per se*. Its foundation started with the establishment of the Association for Coroplastic Studies (ACoSt), and from the idea that the study of the coroplastic should also include the analyses of the context, chronology, function, production, sources and types of clay. Moreover, the Association encourages the study of these artefacts distribution and display, as well as their religious, historical, social, economic, and political context.

coroplastic are significant, opening doors to new aspects of this material, such as the context, function, production, and sources. The field has opened to analytical sciences in a meaningful way, following a similar path to other archaeological disciplines that embrace 3D digital technologies.

Still, the employment of 3D digital technologies in the more recently established coroplastic discipline is limited. There are preliminary efforts, but they aim at visualising artefacts or storing and preserving data. Similarly, some scholars are proposing methods (e.g., databases) to retrieve and classify artefacts, but with no progress.

Beyond the coroplastic studies community, isolated researchers have proposed digital technologies to classify statuary according to style; but these projects do not rely on a standardised procedure. Scholars use digital technologies and systematic procedures to classify other kinds of archaeological material (e.g., lithics, ceramics) or focus on specific case studies.

In addition, concerning the technological and manufacturing investigation in the coroplastic field, some researchers seek to analyse the production *chaîne opératoire*. However, their approaches are experimental, traditional, and qualitative. To improve classifications, the coroplastic field needs a systematic application of quantitative 3D digital technologies for geometric and analytical comparison to support an approach based on the *chaîne opératoire*. The present research locates within the endeavours to develop coroplastic studies as a specialised discipline. Introducing a consistent and standardised 3D digital and analytical methodology can enhance the investigation (and solve problems) of unique characteristics typical of this specific archaeological material.

1.1 Research aims

In this context, the current research aims to:

- Propose a 3D digital and analytical *chaîne opératoire* methodology (the *3D digital approach*) to analyse and study small terracotta figurines based on features that quantitatively characterise the artefacts.
- Understand the function, social role, manufacturing dynamics and context, as reflected by the techno-typological analysis of small terracotta figurines resulting from the *3D digital approach*.

Scholars in the coroplastic field must adopt consistent quantitative criteria to address the problems of subjectivity and repeatability typical of qualitative-based systems. A multi-disciplinary approach that integrates traditional archaeological studies, computer-assisted investigation, and science solves those problems. This research aims to propose a 3D digital and analytical *chaîne opératoire* methodology (also called *3D Digital Approach*) for investigating terracotta figurines based on quantitatively identifying and analysing a set of features describing the artefacts. Such features are quantitative descriptors (3D measurements and analytical information) and meaningful for describing the complete objects' shape, mode of manufacture, and production techniques. They derive from a 3D geometry analysis and material surface[3] characterisation.

More specifically, the purpose of a technical and technological classification based on 3D geometry and analytical investigation is to help identify elements, which we can use to (semi)automatically recognise relationships. For example, technologies might differentiate between shape, production technique, geometric measurements, expertise, patterns, common hands, tools, decorations, pigments, types of objects, material composition, and provenance. The criteria resulting from the geometric and analytical descriptors lead to the creation of classes (clusters) of artefacts which we can then analyse in relative chronological sequence by relating them to each other and within their context.

Case study and complexity

The 3D digital and analytical *chaîne opératoire* method integrates a top-down approach (the setting of 3D descriptors for a classification procedure) with a bottom-up one (the test on a group of terracotta figurines) to validate the process, such as checking an already existing classification or creating it *ex-novo*.

The case study is a sample of clay figurines found at the site of Ayia Irini and named 'small human idols' after the Swedish Cyprus Expedition (SCE) excavations in the 1930s.[4] Located on the northwest coast of Cyprus, Ayia

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[3] The term material surface characterisation, or analysis, refers to the quantitative chemical investigation of the material at the surface level, such as pigments composing the decoration.

[4] The whole set of artefacts found at Ayia Irini is composed of vases, bronze statuettes, and scarabs, aside from the numerous clay figurines representing humans and animals or these categories together. For a more specific description of the collection and its classification, see Chapter 2.

Irini is one of the smallest sites discovered by the SCE in 1929 (Figure 1.1). Since the definition 'small human idols' used by the SCE results from an interpretation, this thesis uses more neutral terminology.[5] In this regard, we use the terms small statuettes or figurines interchangeably.

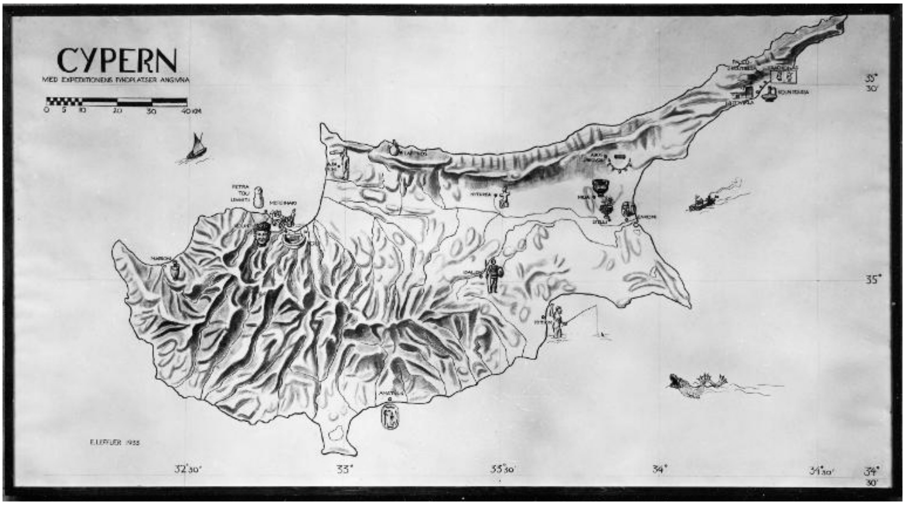

Figure 1.1
Map of 1933 with a visual representation of the archaeological sites discovered by the Swedish Expedition in Cyprus (MM CO5050, Swedish Cyprus Expedition archive[6]).

There are many reasons that the Ayia Irini material forms an optimal case study. The collection is difficult to categorise because of many shared features and similarities. A few years after the discovery, the excavators performed the first effort to classify the finds (Gjerstad et al. 1935).[7] To this day, archaeologists have attributed the small figurines to the Cypro-Archaic I-II, a relatively long period of approximately 200 years. According to the excavators, the site's continuity, identified as an open-air sanctuary, dates more broadly from the Late Bronze Age (Late Cypriot III, ca. 1200) to the end of the Cypro-Archaic II period (ca. 475 BC). A catastrophic flood in the first century BC might have caused the abandonment of the site, then briefly reinhabited. According to Sanne Houby-Nielsen, this dating is based on

[5] The study of the terracotta statuettes did not include fragments.

[6] http://collections.smvk.se/carlotta-mhm/web/object/3996974

[7] See the following chapters.

stratigraphic arguments that need revising (Houby-Nielsen 2016). The scope of the present research is to partly re-examine the site's stratigraphy and identify the artefacts' relative chronological sequences. This step clarifies the function and social role of the sanctuary as reflected by the typo-technological classes of the small terracotta figurines determined with the aid of a 3D digital and analytical methodology and re-contextualised spatially (see Chapters 4 and 5).

By their considerable number and repetitive schemes, the statuettes present an optimal case to study the *chaîne opératoire* in an event-oriented approach. The aim, within this framework, is to discover the mode of production and use it to identify hands, to return the object to the artisan and, again, to insert it in a chronological and spatial context.

The earliest publication on Ayia Irini established a stratigraphy and stylistic development of the 'terracotta sculptures,' also known as the big statues (Gjerstad et al. 1935). Later studies on Cypriot art rely on the results published by the SCE, which informed the chronology of styles in Archaic Cypriot sculpture. Recent scholarship challenges Swedish publications' stratigraphy and classificatory conclusions (Fourrier 2007; Bourogiannis 2016; Houby-Nielsen 2016).[8] My research aims not to validate or contest the laudable work carried out by Gjerstad et al. but to focus on the so-called 'small (and large) human idols,' which were traditionally overlooked since they contributed little new archaeological or chronological information about the site. This research looks beyond the big statues and focuses on the small figurines. In addition to addressing chronological and technical interests, this choice enables a comparison between the SCE classificatory system and the one proposed by this research.

However, all Cypriot coroplastic studies underline the difficulty of analysing the Cypro-Archaic I-II period production. According to Vassos Karageorghis, that is for two primary reasons (Karageorghis 1995: x). First, compared to the Greek tradition, Cypriot art changed more slowly, making it more challenging to identify chronological change.[9] Second, the material is difficult to date; for many Cypriot artefacts, even specimens with a known

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[8] For an overview of the most recent studies, see "The Ayia Irini Project at Medelhavsmuseet, Stockholm" by Georgios Bourogiannis on *Kyprios Character. History, Archaeology & Numismatics of Ancient Cyprus* (http://kyprioscharacter.eie.gr/en/scientific-texts/details/research-projects/ayia-irini-project-at-medelhavsmuseet-stockholm)

[9] Concerning the small figurines, there are hints about the mutual influences in iconography between Greek and Cypriot works of art (Higgins 1954). Differently from the votive offerings of the Greek sanctuaries (usually in bronze), in Cyprus, the choice was for cheap material as clay, often decorated with colours.

provenance, we cannot propose a date more precise than Cypro-Archaic I and II. These subdivisions derive from ceramic styles, covering over 100 years each: approximately 750-600 BC and 600-475 BC. Karageorghis' suggestion that some figurines present the same abstract motives as the Cypriote Bichrome IV[10] ware, adds little to the dating because this pottery style period is equally broad (Karageorghis 1995: x).[11] These difficulties make the collection perfect for a 3D typological approach.

Generally, the studies on small figurines rely on descriptive rather than interpretative data (Walter 2014: 11). A comprehensive categorisation (a *corpus*) of small coroplastic Cypriot-ware does not exist; its study concerns a selection of the material, such as the completeness, the rarity of the iconography and the style, and the certainty of the provenance. As an example, the exceptional contribution of Vassos Karageorghis on the field of coroplastic art in ancient Cyprus is, according to his admission, not comprehensive (Karageorghis 1995: xi). Karageorghis' study reflects the abundant production and the creativity of the Cypriot craft, and it follows an organisation according to typological criteria, sometimes associated with those of size or technique and, as criticised by Sabine Fourrier, who has a

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[10] In his study on the Cypriote Iron Age's material culture, Gjerstad highlights the distinction of two ceramic groups that artisans started to produce already at the end of the Cypro-Geometric III period and that arrived at their peak production during the Cypro-Archaic I period (Gjerstad et al 1935: 775). According to Gjerstad, the South and the East of the island preferred White Painted and Bichrome wares, specifically with floral and figurative decoration; the North and West had instead a predilection for Black-on-Red and Bichrome Red wares, plus a geometric decoration. Although, he states we cannot consider these two distinctions fixed because there are cases of Black-on-Red occurring in the South and East and White Painted and Bichrome found in the North and West of Cyprus (Gjerstad 1948: 461; Gjerstad 1960: 105-107). Other scholars studied the spatial and chronological production and distribution of decorated pottery based on their macroscopic characteristics. In 2004, Nys & Recke reported that only a few mineralogical and chemical analyses on ceramicexisted, with no fundamental results (see Nys & Recke 2004: 213 for further references). However, this topic lies outside the current research, and I refer the reader to related bibliography.

[11] Fourrier (2007) underlines that in Greece it is possible to read the style transversally in the production of coroplasts, sculptors, and painters, because they reproduce the same formal patterns. In Cyprus, the situation is different. This phenomenon is especially evident in the ceramic case, where the human figure is a much rarer pattern; therefore, a comparison is more complicated. In ceramics, as in coroplastic art, there are original productions in Cyprus during the archaic period, distinguished by their morphological, technical, or stylistic choices, which we cannot attribute to distinct creative centres. Moreover, the repetition of the same patterns, both floral and geometric, shows that both painters of vases and coroplasts were using the same decorative *repertoire*.

stylistic approach, more rarely according to stylistic criteria (Fourrier 2007:13).

Similarly, Einar Gjerstad's classification of the Ayia Irini small statuettes was not fully systematic. Approximately dated according to the interpreted chronology of the site, the typological analysis sometimes uses repetitive schemes (the seriality of the material) and sometimes the presence of distinct features. Gjerstad acknowledged that his approach has limitations (Gjerstad et al. 1935: 785-786). These classification systems do not address the repetitive and homogeneous criteria of the small figurines. We can overcome this vagueness by enhancing the descriptive process and using 3D digital technologies to define clusters. In doing so, we can collect evidence related to production methods, analytical characterisation, and errors or variances in production.

A further point of interest that applies to a sizeable serial production is its potential to create production chains. As noted by Karageorghis, the production of Cypriot terracotta figurines of the Cypro Archaic I and II took probably place in the same workshops as vases. This theory does not exclude the presence of coroplasts working independently, as the variety of decorative patterns and lack of painting on figurines suggests (Karageorghis 1995: x).[12]

Similarly, in his seminal study from 1935, Einar Gjerstad emphasises the messiness of the stratigraphy at Ayia Irini. He explains that he found fragments of the small figurines in disturbed disordered layers (Gjerstad et al. 1935). Although he gives indications about the relative position in the space, their stratigraphic attribution is vague. In addition to the semi-circular layout of the statues around the altar, Gjerstad suggests that the small figurines were initially closer to the altar. He argues that floodwaters shifted the small statuettes from their original position; at the same time, alluvium partly or almost covered the so-called "large human idols" (Bourogiannis 2013).[13]

In conclusion, studies of the Ayia Irini excavation and its small statuettes collection suffer from the following problems:

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[12] In general, polichromy appears more often on clay figurines than on vases, and in some places were found samples (especially in Kourion) with a white undercoat as a base for the decoration. This technique may derives from the Greek coroplastic art and, as in Greece, also in Cyprus during the period 600-550 B.C., the potter crafting and coroplastic art separated (Higgins 1954). Concerning the pigments used for the decoration and the manufacturing techniques, cfr. Aloupi & MacArthur 1995; Ikosi 1991; Ikosi 1991-92; see Chapter 4).

[13] It is plausible that all the statues and statuettes belong to a single deposition that can dates to the Cypro-Archaic period.

- Interpretation of the archaeological site lacks clarity due to the unclear stratigraphy (the so-called ‘phantom stratigraphy’ in Houby-Nielsen 2015).
- The small figurines’ attribution spans two centuries.
- The classification system relies solely on visual observations and lacks comprehensive, universal criteria.[14]

Finds like these are both exciting and troubling — the similarity of the objects combined with unclear stratigraphy creates dilemmas for modern-day historians and archaeologists. Thankfully, a *3D digital approach* provides solutions — using innovative technologies combined with traditional archaeological methods, we can create systematic categories that allow a reassessment of extensive collections of poorly studied objects. Focusing on the case study of the small statuettes of Ayia Irini, this research seeks to demonstrate the value of a *3D Digital approach* in coroplastic classification.

A digital approach to the finds of Ayia Irini offers an added benefit – that of reuniting the collection virtually. Historical agreements separated the finds between Cyprus and Sweden. In Cyprus, the Ayia Irini collection accommodates at the Cyprus Archaeological Museum in Nicosia; in Sweden, the bulk of the collection is at the Medelhavsmuseet, while subsets are at the Lund University Historical Museum (LUHM), the Gustavianum in Uppsala, and the Malmö Konstmuseum. This division limits holistic vision and comprehensive analysis. Rather than attempting a comprehensive study of the small statuettes of Ayia Irini, the focus of the current study is to demonstrate the benefits of 3D digital documentation to virtually reunite archaeological collections for comprehensive research, data re-evaluation and holistic, diachronic approaches. For these reasons, the case study samples material from present locations.

This study does not aim to attribute the small statuettes or the site chronologically, but the intention is to discuss what we can further learn about their production.

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[14] Besides the past studies, further ones are recently running on different aspects of the Ayia Irini archaeological site: the analysis and re-interpretation of the stratigraphy through the excavation diaries and the grey literature; the study of the pottery from different periods and the analysis of the faunal remains. Only one study focuses on coroplastic production, from a chemical point of view, to identify the material and the geographical provenance of the workshop/s. The scholars presented the results of these studies in May 2015 at the conference “Ancient Cyprus today: Museum collections and new Research Approaches to the Archaeology of Cyprus” (Stockholm, 25-27 April 2015) and in a publication (Bourogiannis & Mullenbock 2016).

Moreover, the characteristics of the Ayia Irini small statuettes and the methodology used in the past to study them determine a series of archaeological research sub-questions, which I will tackle in the following related chapters.

Significance of the study

Specific research questions require new methodologies (Foka et al. 2020: 1). With this in mind, the research questions deriving from the complexity and richness of the coroplastic discipline and the proposed material need a specific methodology to consider the limitations set both by data and previous studies.

The results of this research contribute to developing an innovative method based on 3D digital and analytical *chaîne opératoire* investigations for studying coroplastic. Furthermore, this research enhances our knowledge of Cypriot coroplastic technical and technological production in general and Ayia Irini and its surrounding in particular. The choice of single groups or a small number of figurines might limit understanding. However, I hope to gradually expand to a more comprehensive approach that includes a broader context and comparative examples after conducting a detailed analysis of a small sample.

This research proposes a scientific method based on geometrical and surface material analysis using an open and transparent process that rely on clear parameters and verifiable experiments to validate a hypothesis (Vico Lopez & Vassallo 2013). The proofs of the scientific method and the empirical sciences, as proposed by the Popperian empiricism (Popper 1959) and based on the *chaîne opératoire* framework, explained in terms of *connaissance* and *savoir-faire*, verifies the potential of the typo-technological analysis of the small figurines of Ayia Irini for the interpretation of the Archaic small coroplastic production of Cyprus. The *chaîne opératoire* framework finds trends, modes of production and specific hands or workshops using technical and technological traits identifiable through various quantitative attributes and criteria.

The *3D digital approach* overcomes the problem of subjective classifications and provides a consistent set of criteria for a meaningful comparison. Equally important, the flexibility of the method lends itself to other objects of material culture and different periods, making the interpretative process formal, measurable and transparent.

1.2 State of the art in the field

Theoretical background and earlier research

The current study lies between archaeology and digital technology, developing a cross- and multi-disciplinary methodology to classify and interpret coroplastic objects. A critical contribution of this research is creating a new framework called the *3D Digital Approach*, whose methods rely on theoretical principles and literature from archaeology and digital technology. I will start with archaeological classification theories, including the typo-technological system, the theoretical debate, and the latest digital approaches and 3D applications. Then, I will focus on coroplastic studies by presenting the approach adopted by this dissertation, which is based on the *chaîne opératoire*, and how technology (e.g., digital, analytical and semantic) can support this kind of analysis.

Archaeology, visual approach and classification

Some decades ago, the common thought was that archaeology was an ‘undisciplined’ discipline since it existed between objectivity and subjectivity, materialism and idealism. Until the 1950s, archaeology was, as David Clarke famously opined, “an undisciplined empirical discipline” (Clarke 1968: xv). Influenced by scientific disciplines, including chemistry and biology, archaeology implemented new schemas, rules, and procedures that systematised archaeological processes and interpretation. Nevertheless, these changes did not affect how archaeology looks at reality, both from a descriptive and an interpretative point of view.

As stated by Juan Barceló and other scholars, “archaeology is a quintessentially visual discipline” (Barceló 2010: 93; Moitinho de Almeida 2013), and it has always been “intimately connected to the modern regime of vision” (Thomas & Jorge 2008: vii).[15] Documentation of finds, ruins and cultural materials relies on visual methods. In the late nineteenth century, photography joined drawings as the primary tools for documenting and publishing archaeological discoveries. (Hamilakis 2001: 9-10; Guha 2003: 1-3; Smiles & Moser 2005: 4-6; Barceló 2000: 9-36). New techniques, such as aerial photography, photogrammetry and 3D digital visualisation, have recently enhanced archaeological documentation.

[15] Recording, description and interpretation have always been visually (Jones & Bonaventura 2011).

The same happens concerning the interpretative process. Our eyes are the first tool for categorising the objects around us; we view the object and immediately connect it with similar objects from our experience. Therefore, the same process occurs when an archaeologist excavates an object: the first step is to identify what that specific object is (e.g., a ceramic fragment, a chipped stone, a statue) and then to set that object in a spatio-temporal, social, or cultural context. The first step consists of visually identifying the objects; successively, we consider other elements to understand how people of the past produced and used those objects (Hodder et al. 1995: 16).

Shapes, colours, and details are all elements that the brain associates with something already known. They become images or constructions with meanings; the brain makes them semantically coherent, creating - in this sense - the reality (Bressan 2007: 47, 119). The division between observation and mental speculation is a well-known concept. For example, Descartes explains that while the eye gives the input to the brain, it is the brain that 'sees' (Smith 2018). This procedure is not void of subjective interpretation, as what we see is "what we have been trained to see" (Barceló 2010: 93). This critical observation sparked the current research. Cultural background drives our perception, which is the *pre-understanding* and *precondition* of our further observations or interpretations (Taylor 2006: 317-336; Wrathall 2000: 93-114). Thus treated, the explanation of the past emerging from our interpretation of an artefact is the result of our subjective way of seeing that artefact (Barceló 2000: 9). Theories of knowledge depend on the background and training of individual scholars, who, as stated by Bronowski, still rely on "hunches, and leaps of faith" (Bronowski 1978: 35). As a consequence, a partial knowledge can bias everything.

Therefore, the further step is to codify the objects within a context to understand what they are and represent. Humans rely on their perception to organise objects into categories and classes.[16] We build associations as soon as we connect details of an object with corresponding features in one or a sequence of objects (Barceló 2009: 94-95). According to Aristotle, we know something only if we classify it and identify its properties (*Cat*. 4, 1b25–2a4; Ackrill 1963: 5). Therefore, classification creates knowledge through establishing schemas that represent entities and their inter-relations.

[16] This information structure helps human capacity to simplify complex wholes into small ordered groups and avoid the difficult management of individuals while tracing variations within and between groups. We can classify a phenomenon on the basis of specific characteristics such as size, shape, colour, and material. Once having a classification, it is possible to start analytical work on data and to test the validity of the units determined by the classification itself (Lyman & O'Brien 2002:73)

Classification schemas allow scholars to order the entities and their relations to further knowledge about a specific domain.

Classifying artefacts is a standard archaeological procedure (Adams 2010; Read 2007). For instance, Benjamin Irving Rouse highlights that, through classification, it is possible to place culture in a chronological or spatial framework (Keegan 2009: 6, about the work of Rouse 1939; Rouse 1960: 313) and to discover related knowledge. This process helps the archaeologist order complex groups of objects (characterised by numerous variabilities) by creating classes of objects composed of smaller manageable units (Shipton et al. 2016). Therefore, archaeologists regularly classify and categorise material remains to determine time sequences, cultural affiliations, influences or stylistic development (Pollock & Bernbeck 2010: 37; Alexandrou 2016: 127[17]).

Another important aspect of understanding archaeological objects is to extract information that clarifies their function in the past as an object, as a human production, and as an expression of a society. Therefore, an archaeologist must document an artefact's details and characteristics to identify the similarities that make it belong to a specific category or class. The dissimilarities can indicate variances regarding that class or sharp changes that make them belong to a completely different class. Once again, the study of objects in modern Western archaeology uses classification models that follow visual analysis and the archaeologist's comparison between approximate shapes and geometries of similar artefacts, recording and analysing the components of each artefact's shape (Miller 1985: 51-74). A lack of systematisation and standardisation in the documentation, a deficiency of measurable information and a consequent "blurry" description can bring a subjective interpretation of the object and its relation with other similar objects. What someone decides to perceive or record might be completely different from someone else's choice: if we do not explicitly define the characteristics or criteria of the artefacts, this can determine a non-comparability among them. Moreover, the validity of the groups created

[17] That is not an easy task since an archaeologist has to consider different elements to compare many objects (or fragments), detect all possible patterns and decorations, materials, and finally consider all this data to cluster similar artefacts appropriately. In general, archaeological artefacts and cultural heritage assets are for their proper nature very complicated since they bring along various information (e.g., geometry, texture, decorations, shapes) that make their organisation into meaningful groups difficult (Biasotti et al. 2016b: 5). This kind of activity can be even more complicated if it runs across collections and across collections that are physically distant from each other, like in the present case study.

should always be verifiable by tests (Lymar & O'Brien 2002: 81). The use of not-well-defined criteria, plus human error and other theoretical and practical biases (Beck & Jones 1989), can bring inconsistency in classification and, consequently, the impossibility of understanding the classes created by others and their interpretations (Whittaker et al. 1998).

Therefore, classification and knowledge influence each other in both a positive and a negative sense. On the one hand, the human capacity to store and retrieve vast amounts of information permits classification to interact with prior knowledge and enhance further knowledge acquisition. Indeed, the relation between knowledge representation through classification and new knowledge discovery bounds to a creative process in which the final step is the theorisation of a concept (Kwasnik 1999: 22; Kwasnik 1992: 63). Theoretically, the use of classification promotes discovery and the creation of new knowledge. On the other hand, by breaking the material down into smaller parts, classification risks constraining our comprehension and limiting the discovery of new knowledge.

To summarise, even within a multi-disciplinary and technological era, the analysis of archaeological material continues to rely on visual and qualitative methods. The consequential classification can suffer from biases and lead to limited knowledge and interpretation. This research proposes a solution to these problems by creating a standardised description[18], systematisation, and material classification based on quantitative criteria to limit biases.

A historical overview of archaeological classification

Several scholars have used classification methods in archaeology with different results and purposes, while others question the fundamental values and limitations of the process.

Although with no clearly outlined principles, the 18th century Winkelmann's work is the first attempt to develop a classification system. He proposed new criteria for the scientific study of antiquity and the chronology of ancient sculpture based on stylistic categories (Winkelmann 1764). Only in the 19th century did scholars start to use classification to order material chronologically in a more structured way, following the scientific rules of the principles of evolution. Darwin's Theory of Evolution influenced scientific and humanistic studies during those years. For instance, the archaeologists Pitt-Rivers (Pitt-Rivers 1894), John Evans and Oscar Montelius (Montelius

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The standardisation concept is another essential element of this research since standardised descriptions and data enable interoperability in classification, data integration, and retrieval within digital information storage.

1885; 1899; 1903) applied Darwin's theories to archaeology, developing theories and typological studies that form the basis of modern archaeology. During this period, with the emergence of the experimental method applied to historical scholarships, archaeology became 'science' and acquired full awareness of its nature and objectives: 1) monuments and ancient remains represent material evidence for the reconstruction of the past, 2) scholars systematically collect, study, classify and interpret archaeological data through typology (e.g., the contextual seriation method in Petrie 1899: 295-301), and 3) comparisons, studies of typologies, and chronology replace the antiquarian-oriented discourses(Pallottino 1968: 28, 34).

During the 20th century, the study of archaeology moved from a pure historical-artistic analysis[19] to research also based on sociology and anthropology and with interests in classification and techniques (Bianchi Bandinelli 1994: xxii). The first half of the 20th century was characterised by a 'morphological type' classification conducted in a non-critical way and applied to non-contextualised material or sites excavated without a proper stratigraphic method. During this period, classifications relied on the physical traits of the objects, clustering items into classes characterised by shared features, such as form and colour (McKern 1939: 301–313). There was little attention to objects' cultural history, production, or function. This approach also determined a classification based on scholars' skill and experience and through visual comparisons, without an objective explanation of the criteria used (Adams 1988: 41; Ford 1954: 43).

Nevertheless, the primary interest in anthropological aspects brought a change of perspective in classification studies. The attention to classifying artefacts was put on traits that represent the cultural behaviours of the makers and users (Rouse 1939; Krieger 1944). Shifts in anthropological research influenced archaeologists to rethink classification and its purpose: on the one hand, some scholars argued that classification should seek to discover the 'ideational domain' of the maker (Read 1989; Read 2007); on the other hand, scholars proposed to use classification as an instrument to answer specific research questions, thus transforming it into a creative process of the archaeologist (Spaulding 1953; Ford & Steward 1954; Dunnell 1971; Dunnell 1986; Adams 1988; Adams & Adams 1991; Adams 2010[20]). Also,

[19] At the beginning of the 20th century, time and space became the focus of classification, determining the so-called *style* or *historical type* (Lyman & O'Brien 1997; Lyman & O'Brien 1998; Lyman & O'Brien 1999).

[20] Adams provides a synthetic summary of the different typologies, useful for approaching a classification methodology in studying archaeological material and related to the different views in the theoretical debate cited.

some authors connected variability with function or adaptation, while others considered cognitive approaches (Bordes 1961[21]; Binford & Binford 1966). During this time, a “typological debate’ emerged. Proponents promoted relationships between artefacts as the crucial factor for classifying material culture. In this method, we classify objects based on the presence of other objects, their geographical location, date, and period (Dunnell 1986; Trigger 1989: 20-21; Palincaş 2005: 220).

Processual archaeology, which relies on a rigorous application of the scientific method, emerged in the second half of the twentieth century, accompanied by a debate about the use of automatic classification (Renfrew 1987; Krieger 2012; Renfrew & Bahn 2006). A computational mathematical approach is the latest addition to the theory of archaeological classification (Benfer & Benfer 1981; Read 1987; Read 1989; Read & Russell 1996). However, during the late 1970s and early 1980s, a post-processualist theoretical movement caught on, questioning earlier theories and positing that archaeological interpretations are never entirely objective, even if the scientific method is applied. The post-processual theories instead emphasise that archaeology is subjective since “the truth [that] could be ascertained from the archaeological record was often relative to the viewpoint of the archaeologist responsible for unearthing and presenting the data” (Trigger 2006: 451-452).

Although post-processual research was initially born as a reaction and critique of scientific objectivity, later reviews show that it is scientific and can contribute to a scientific understanding of the archaeological record (vanPool & vanPool 1998: 33). Later post-processual points of view and evolution into post-modernist theories advocating for interdisciplinarity and multivocality demonstrate the same (Knapp 1996: 127).

The choice of a typo-technological classification

Usually, archaeologists interchange the terms classification and typology. However, differently from the term classification used to indicate any set of formal categories into which a group of data is divided, typology designates a more rigorous type of classification in which categories are defined by the same and exclusive criteria (Adams 2010: 136: Bortolini 2016: 11).[22] The

[21] After Bordes, typological research became one of the fundamental tools in establishing chronological frameworks or comparisons between assemblages and archaeological sites (Hermon 2008: 17).

[22] Irving Rouse declares: “classification consists of forming successive series of classes, referring to different features of artefacts. Each class is characterised by one or more attributes which indicate a custom to which the artisan conformed, for example, a

arrangements depend on the definition of the criteria's importance and the purpose of the artefacts classification (Ford 1954).

Physical characteristics, such as shape, size, weight, measurements, and colour composition, allow comparative, quantitative analysis for the investigation of production, including techniques, specialisation, knowledge and expertise. Thus, in this situation, we must apply a typo-technological classification system. However, how can we be sure that our classification is valid? There are additional limitations and biases beyond those raised by the classification debate[23] (Hodder & Hutson 2003: 26-27; Palincaş 2005: 221). Changing social and cultural contexts in the present affect the interpretation of the material (Hodder & Hutson 2003: 18-19). Another bias derives from categorising objects: the archaeologist might apply contemporary meanings in producing classes, thus distorting the original use.[24] Moreover, one could argue that the critical comments to categorisation advanced by Hodder & Huston (2003) relate mainly to hypotheses concerning function, but this does not go much far from any other interpretative needs deriving from classification (e.g., attribution to a class based on production's criteria) and that we have to take into consideration for our results theorisation.

Archaeology, like all academic disciplines, suffers from human biases and cultural subjectivity; in recent decades, scholars have turned to computer science to minimise these limitations (Hodder & Hutson 2003: 180). My research seeks to use technology to remedy the vagueness of traditional qualitative approaches and their consequent subjectivity. The post-processualist theory applies equally to my research since it underlines that also in digital procedures researchers make choices that affect objectivity. Nevertheless, in contrast to traditional methods, the digital approach redefines and shares the classification algorithms, rendering the interpretative process transparent, the operational choices traceable, and the results reusable.

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manufacturing technique, or a concept which he expressed in the artefacts, such as a design", (Rouse 1960: 313).

[23] Theoretical debate focused on the approach used, if the classification derives from our modern perspective, or from the past people, either 'emic' (Hutson & Markens 2002 for a thorough discussion on the emic debate) or 'etic', point of view.

[24] It is important to consider that classifications change with time. Critical theory has changed many classifications: for instance, critical lenses such as post-colonial or gender studies have changed the way we classify today (see Gosden 2012; Hamilakis 2008; Stockhammer 2012).

Digital technology for classification and typology

Thanks to the accessibility of digital technologies in the Cultural Heritage field, researchers have used new methods on various archaeological materials to address a wide range of research questions (see Patay-Horvát 2014, 2015; Bevan et al. 2014; Barmpoutis et al. 2015). In some cases, technical procedures and mathematical approaches shifted the results of previous classifications and interpretations (Shipton et al. 2016; Trinkl et al. 2018). Especially in the last few years, recent approaches from automatic subject classification, pattern recognition, machine learning, and data mining to classification in the semantic web contexts increased (Nakoinz & Hinz 2018: 113-119; Nakoinz & Hinz 2019: 206-215). Nevertheless, Nakoinz & Hinz (2019: 206) demonstrated that only some case studies use digital procedures. For a variety of reasons, the majority of interpretative studies still rely on traditional methods. Some researchers incorrectly view digital procedures as cumbersome, while others erroneously perceive the results as general or reductionist.

Recent projects funded by the European Union testify to the recognition and need of the scientific community for technological-driven research in Cultural Heritage and demonstrate a process of integration towards the technological approach in the study of archaeology specifically. In particular, two projects well represent the recent efforts in that direction: GRAVITATE (https://gravitate-project.eu/), which developed a system based on 3D geometry, shape analysis, colour features, semantic metadata and natural language processing for re-unification, re-association and re-assembly of statues and statuettes assemblages; and ArchAIDE (http://www.archaide.eu/project) that, instead, developed a system for automatic pottery recognition and classification based on machine learning algorithms for decoration and shape.[25]

Although archaeology has yet to embrace computational methods fully, computers already solve problems, including determining and managing typologies and transforming features into quantitative elements. However, subjectivity is still a problem; some scholars argue that these methods assume that the analyst makes decisions before and after running the analysis (Voorrips 1982:93-126; Adams 2010: 139), and therefore these interventions would not remove the bias since the archaeologist system of meaning

[25] This direction of the research is significant in consideration of the classification within the frame of the semantic web and how the use of structured data (e.g., metadata, ontologies, gazetteers) could help in enabling interoperability in classification, usability, user need and consequent implementations (Vidal-Castro et al. 2010; Pomerantz 2015).

intervenes in the selection of both the variables and the specific algorithms to use (Dunnell 1986; Read 1989; Hutson & Markens 2002).

Archaeologists need to choose data for classification; nevertheless, their human ability cannot distinguish or elaborate all the characteristics of artefacts because of their high number or small dimensions (Palincaş 2005:241; Adams 2010:139).[26] In these cases, mathematical methods are instrumental. If, on the one hand, technology is the means to pursue objectivity, on the other hand, it is important to underline that even technology is not completely neutral (Foka et al. 2020: 27). Any tool presupposes a set of different choices: for instance, which material to select and use for analysis, and the technical steps to follow during the interpretative process (see Chapter 3). Technology can, if applied correctly, bring new research questions and new knowledge to the field of Cultural Heritage.

Like human brains, computers elaborate information and associate specific features into groups (Barceló 2009). The use of technology does not erase the need for human analysis and observation, and traditional visual analysis must integrate with technologies to produce more accurate results. When a class has clear rules, well-defined criteria, and consistency, different analysts can use it to make conclusions. The quantitative expression of the variables (e.g., the quantitative 3D description of the objects, multivariate analysis, clustering analysis) serves to define and discover types or classify artefacts, reducing human error and bias.

For instance, artefacts appear similar to the naked eye. However, after measurement and analysis (e.g., statistical method or 3D geometrical comparison), computers can identify features associated with a specific artisan's hands. For example, Impey & Pollard (1985) used a multivariate metrical analysis to demonstrate that similarly-shaped objects by different potters exhibit individual characteristics.

The employment of 3D digital approaches helps to solve some of the issues caused by a traditional classificatory methodology:

- Precision and accuracy
- Consistency[27]

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[26] Hutson & Markens (2002) write about how many archaeologists tried to avoid objectivity by building emic artefact classifications or applying numerical methods (Clarke 1968; Read 1982, 1987, 1989; Read & Russell 1996; Benfer & Benfer 1981; Spaulding 1977; Cowgill 1990).

[27] Fish (1978:86-89) and Whittaker et al. (1998:137-138) are among the few archaeologists that treated the issue of typological consistency and quality control in the classification domain.

- Ambiguity (e.g., How can we approximate/attribute a form to a geometric shape? How can we evaluate the variations of that shape? How straight is a straight line?)
- Reliability – outside researchers can repeat the process
- Relatability –different observers understand the type sets.

Doran & Hodson perfectly express the best compromise between traditional visual methods and technical ones:

We do not believe that intuitive classification by archaeologists [is] necessarily invalid. On the contrary, the visual appreciation of complex morphological patterning is a major human ability which would be perverse to discount […]. However, it is clear that the innate abilities for pattern recognition that archaeologists may possess are rarely controlled sufficiently for consistent, communicable classification to result (Doran & Hodson 1975: 186).

The use of digital technologies in this work allows the development of classifications that enhance our capacity to discover new information and knowledge based on human mind structures and measurable analyses. The elaboration of measurable characteristics becomes a verifiable test that can help confirm or reject the archaeologists' classification and consequent interpretation made based on only visual analyses. One of the main problems of this approach, particularly clear at the beginning of the "digital turn" in archaeology, is that the Western intellectual tradition is ocular-centric, meaning that vision is the means of knowledge and interpretation (Evens 2005: ix). For that reason, especially at the beginning of the Virtual Archaeology establishment, 3D representations are the "expression of how existing digital tools carry assumptions of knowledge as primarily visual", continuing therefore to support the already cited ocular-centric tradition typical of the humanities research (Slaney et al. 2018: 1).

Technology has changed how we study the past (see Schreibman et al. 2004; Forte 2010). Digital technologies bring opportunities and challenges: new insights encourage debate and new areas of inquiry. That is precisely how digital representations of archaeological data challenge the current knowledge frontiers and generate new research questions, methods and solutions (Foka et al. 2018: 1-2; Foka et al. 2020). That follows the concept of cyber-archaeology as treated by Maurizio Forte (2010) when he states that it would be wrong to speak about the 'reconstruction of the past'. Indeed, Forte recalls a peremptory idea of generating pre-set knowledge without considering what is 'probable'. Therefore, 'probable' knowledge cannot be a consequence of a reconstruction *tout court* but better of a simulation. This thesis treats technology as a 'simulation' of possible events and a valuable resource for formulating hypotheses and critically evaluating the past and its material production (Foka et al. 2018: 3).

Coroplastic studies: the study of terracotta figurines

Since the early nineteenth century, terracottas have captured the imaginations of scholars. After initially treating them as collectable antiques, they shifted to more specialised studies focused on classifying finds based on specific characteristics and materials to encourage more nuanced interpretation (Huzey 1882; Huzey 1923; Walters 1903; Winter 1903).

In the last decades, we have seen an increase in the quantity and quality of scholarship on terracotta figurines, with researchers focusing on iconographic and typological perspectives, including the study of the moulds and mass production processes. In particular, new research has established a better understanding of the role of these artefacts in religious, social, and economic contexts. For example, we have learned a great deal about the importance of these items in daily life and why and how people created them. Material and technical analysis is one of the most exciting and promising areas of study; by establishing the source of materials and modelling procedures, scientists have shed new light on the art of making in ancient societies (Caubet 2009: 43-44; Uhlenbrock 2009).

While some scholars exclusively rely on a stylistic approach, others have adopted a more technical method that Richard Nicholls (Nicholls 1952) first proposed. In defining three categories, typological, stylistic and technological, Nicholls created a foundation for a new perspective.[28] To date, the common archaeological approach to studying terracotta figurines focuses on their documentation and cataloguing by 'type'. This approach allows researchers to detect and document patterns in extensive collections of artefacts, including the division of tasks in workshops, hierarchies of skill, provenance of materials, and types of tools (Langin-Hooper 2014: vii; Muller 1997; Muller 2000; Muller 2014). This thesis seeks a similarly comprehensive approach that establishes information about figurines through their materiality and manufacture; to accomplish this goal, I developed and applied a *chaîne opératoire* approach to analyse a maker's manufacture, choices, expertise, and possible errors.

[28] Although Nicholls originally used the term 'mechanical', scholars have since adopted 'technological' to name the third category. In 1952, Nicholls underlines that, even scholars wrote extensively about ancient terracotta figurines and their organisation into groups, there is no attention to the principles adopted and used for such classifications (Nicholls 1952: 217).

Production data and artisan tradition: a research hypothesis

The term *chaîne opératoire* means operational sequence, and it consists of a "series of operations which brings primary material from the natural state to a fabricated state" (Cresswell 1976: 6).[29] The expression '*chaîne opératoire*' appears for the first time in the work of André Leroi-Gourhan (Leroi-Ghouran 1964-1965: 33), who uses it in an anthropological approach that is more 'cognitive' and neo-evolutionist than technological (Djindjian 2013: 93). This research focuses on the technical aspect of the term and the descriptiveness for analysing the process. It considers the concepts of *connaissance* and *savoir-faire* as treated by Marcel Mauss (1950), Leroi-Gourhan (1964–1965) and Pierre Bourdieu (1977), who refer the first term to the discursive knowledge and the second to the practical knowledge, know-how and habitus. Moreover, this study directs attention toward the more detailed distinction of the concepts elaborated by Pelegrin (1990): knowledge (mental representations), ideational know-how (the sequences of production and comparisons of materials) and motor know-how[30] (the intuitive operations). Indeed, these distinctions help identify the various production events and the causes: the maker's skill and level of expertise, the technique used, or the introduction of a trait by a specific artisan.

The 'Morelli's elements' similarly express the previous concept (Morelli 1893; Wollheim 1973): they are specific recognisable technical details that the artist always uses and can help to determine the paternity of an artwork and its production sequence.[31] Although it might be disputable to apply this art history approach to more artisanal production and consider it "inappropriate when transposed to a prehistoric […] context" (Morris 1993: 43), some researchers support the concept of distinguishing individuals' works through the identification of personal characteristics connected to intuitive operations. According to them, these elements represent strong theoretical evidence for detecting even an anonymous prehistoric artisan regardless of his/her artistic self-consciousness (Morris 1993: 43). A limited number of archaeologists used this approach for the identification of hands in pottery decorations (Beazley 1922: 75-90; Benson 1961: 337-347; Morris

[29] The topic is the core study of several French scholars (Pelegrin et al. 1988; Pelegrin 1990; Pigeot 1990).

[30] The motor know-how is also known as 'motor habits' or 'motor performances' (Hill & Gunn 1977: 2).

[31] Within this social structure, the technical and iconographic background of the tradition could allow the most talented artisan to reach high quality and specialisation and bring small changes that are expressions of his genius and his sign (Bianchi Bandinelli 1994: 121).

1993: 47-54), and very few in terracotta statuettes production (Morris 1993: 51-56; Alexandrou 2016). Only one case (Bevan et al. 2014) accounts the Morelli's elements approach as a paradigm for explaining the stylistic identification of authorship in the production of terracotta statues through computer vision investigation. To a certain extent, the latter resembles this thesis' case study since it is a craft 'in-series' production where the presence of different and recurrent elements can be meaningful for their interpretation.

This *chaîne opératoire* approach presupposes an analysis of the artefacts based on the French Structuralists' relations between culture and techniques (Durkheim & Mauss 1903, Lévi-Strauss 1976; Mauss 1941).[32] Specifically, according to Pierre Lemmonier, the relations between material culture and society converge into the study of conditions that reciprocally transform a technical system and the society's organisation in which it operates (Lemmonier 1976; 1986). An essential aspect of this theory is observing technical variants, and explaining those technical variants helps to identify and discover sociocultural variances. Therefore, technical knowledge is an expression of the relation between techniques and society (Hermon 2008: 13). All the operational sequences (*chaîne opératoire*) that give information about the action performed, the tools used, the material and the actor constitute the base of this "anthropology of technique" (Lemmonier 1986: 147-186). The artefact represents a product of a social organisation (society, group, age, class), and variations in the technical processes are expressions of "choices" of those who apply the techniques (Lemmonier 1986).

To some extent, we can apply this approach to the Ayia Irini small figurines, assuming that the differences in the production refer to the sociocultural background of the individuals within the same group (different artisans, different skills, and different levels of experience). According to Lemmonier (1986: 173-176), a technical choice would imply a specialisation in the production for two main aspects: ethnic identity and economic necessity. If we apply Lemmonier's thoughts to an inter-group division of work or specialisation in the production of different things, this would confirm the 'significance' of the technical choice as a consequence of an economic necessity. If we restrict our focus to a specific group, namely the terracotta artisans, we will find the same factors/dynamics of society. The choices in technical production are means to spot an artisan's identity. Therefore, applied to the case study, I believe these differences operate

[32] Thanks to the "French Structuralists" studies classification became a real subject of research. From this point onwards, for example, in prehistoric archaeology there was a new fervour to start systematic classifications of artefacts (Palincaş 2005: 219-248).

between groups, where technical choices identify different cultures, and within the same group, where they express age, sex, and specialisation—moving from a typical post-processual framework, 'process' and 'agency' become essential factors in this research. Agreeing with Hodder & Hutson (2003: 208) that archaeologists usually set their material into predefined boxes (e.g., style, cultures or systems), I propose to create approaches to typology less characterised by the definition of types *tout court*, but more attentive to the description of the multi-dimensional variability in the type due to individual's agency.[33]

Beyond the study of the statuettes' life-after-creation (e.g., the use and function), this research *chaîne opératoire* approach allows the creation of a narrative between the artefact, the maker and the socio-historic context. A path that starts from the idea[34] to the materials' procurement and the artefact's production aims to identify recurrent and similar elements ascribable to specific hands: a "de-composition agency" into artefacts' components analysed temporally (Hodder & Hutson 102-103). Moving from the Structuralist analysis having the relationship between parts at its base, the assignment of concepts to parts and whole (Leroi-Gourhan 1965; 1982) become paradigmatic in this work. Rigorous analysis of observable data is another element according to which the structures and the conceptual schemes must be experimental and measurable (Hodder & Hutson 2003: 46). In general, the possibility to identify actions on the artefacts that represent the artists' knowledge or individuals' agency supports the technical and technological classification and, therefore, the creation of statuettes' groups attributable to the same hand or workshop.

In general, concerning the *chaîne opératoire* approach, beyond the studies on lithic (Pelegrin et al. 1988; Pelegrin 1990) and those on ceramic (Roux 2016), there are few studies about its application on coroplastic. Predominantly, they approach the topic from a traditional and experimental archaeology point of view (Muller 2000; Muller 2014; Alexandrou & O'Neill 2013; Alexandrou 2016; Alexandrou & O'Neill 2016; van Rooijen 2013; van

[33] Specifically, as Jones (2009: 88) highlights, each artefact retains in itself the maker's agency and therefore makes it possible to identify and represent the specific choices of the makers themselves.

[34] This kind of analysis based on an event-oriented approach (Coburn et al. 2010; Doërr & Kritsotaki 2006) allows for generalising the production and developing an event-oriented analysis that does not convey just the will of the creator in producing a specific object, but it expresses the relations between a 'first' and an 'after' and a technical (and repetitive) representation of an idea, an iconography (the so-called "iconographic persistence" in Loewy 1909).

Rooijen et al. 2017), and a 3D digital approach is missing, representing a gap that this research wants to fill. The presence of the artisan tradition in ancient art implies the persistence of iconographic schemes and individual elements reproduction that we can use as criteria and attributes for classification with digital technologies.

3D digital technology for coroplastic studies

It is only recently that scholars started to study terracotta figurines with different methodologies and mainly following two trends: one analytical and one digital, although the second is still, in my opinion, limited to some aspects and not integrated with the first one. The last decades' technological advancements allowed the scientific and quantitative investigation of terracotta figurines and the development of the two approaches. Concerning the analytical one, several studies focused on different aspects such as the clay structure aiming at the identification of raw material and geological provenance patterns in the assemblages or the pigments characterisation (Dikomitou-Eliadou et al. 2013; Raffiotta 2014)[35], demonstrating a more advanced development of that approach applied to coroplastic studies respect to the other one. The digital investigation shows a diversified and not homogeneous development to the study of terracotta statuettes that goes from cataloguing and visualisation to computer simulation of figurines distribution or reconstruction of artefacts circulation through social networks. In general, all these kinds of analyses demonstrate that the traditional approaches to the study of coroplastic received a pulse towards the search for quantifiable data to respond to different questions. The dynamic showed an application of the quantitative approach to the context rather than the figurines themselves, trying to reconstruct their use and significance by focussing on circumstantial data. The other step attests to a growing interest in the figurines and an increasing focus on physical characteristics, including measurement and texture; however, the work still relies on the subjective characteristics of iconography and style. In her introduction to a volume of selected papers produced in the context of the Association for Coroplastic Studies (ACoSt), Langin-Hooper describes these new approaches in the field. She characterises them as an attempt to introduce a "methodological rigour" already well-established in other archaeological fields like ceramics into coroplastic, a field characterised by a traditional, qualitative approach (Langin-Hooper 2014: x-xi).

[35] For further specialised reference on the topic, see Les Carnets de l'ACoSt bibliography.

Different examples show this trend. For instance, Ramazzotti proposes qualitative-quantitative studies of the context combined with physical breakage patterns of the statuettes to obtain information on distribution and social components (Ramazzotti 2014: 39-64).

The tendency to focus on the figurines as art objects can be seen in the work of Morris & Peatfield (2013), where the digital approach limits to cataloguing, recording and visualising coroplastic material. They aim to create an online interactive repository of 3D models where researchers can closely examine the statuettes by rotating them 360°. In their work, Sarri & Athanassopoulos (2018; 2020) explore the contribution and value of 3D technology for the study, dissemination and digital preservation of terracotta figurines as the basis of a digital database where researchers will locate artefacts for manual comparison. Averett & Counts (2014) and Counts et al. (2016) used 3D digital analysis in a pilot project to join fragments of terracotta figurines based on already-established typologies. This pilot project demonstrates the technique's viability for digital (but still manual) comparison, something that instead the more recent project GRAVITATE further expanded to matching and joining fragments and brought to an automatic level.[36]

Similar to the current study, Papantoniou et al. (2012, 2017) proposed a method to study Cypriot Hellenistic-Roman terracottas to assess the assemblage using stylistic, analytical and digital methods. Nevertheless, concerning several of the proposed aims, the contributions still show an "ongoing state" of the studies and, among the 3D techniques (e.g., digital restoration, database, fragments matching), is missing one finalised to classification. Indeed, unlike the current study, the classificatory analysis proposed by the authors mentioned above does not involve computational methods and is still based on typological, stylistic and iconographic analysis of the figurines by employing art historical examinations.

All the reviewed contributions show the introduction of 3D digital technologies in the coroplastic field, but much of the research fails to reach beyond visualisation, digital data preservation, and fragment matching. There is an interest in fostering the use of digital technology with plans, still at the level of the proposals, of introducing retrieval and identification tools for classification. For instance, Muller & Uhlenbrock proposed to develop a database as "a self-identification tool for classifying new coroplastic types that are either complete or are important fragments" prior to the

[36] For a complete literature produced by the project, see http://gravitate-project.eu/?q=content/articles

"establishment of objective criteria" (Muller & Uhlenbrock 2015: 2-3). However, to date, the proposals mentioned above resulted in a stuck project suspended completely (Muller & Uhlenbrock 2018: 2).

The introduction of 3D digital technologies in the coroplastic discipline as an investigation tool, specifically for automatic classificatory analysis, is still limited (see Chapter 4 for further references): the categorisation following intuitive assumptions and a qualitative procedure is predominant. This thesis seeks to address the gap identified in coroplastic scholarship concerning the need for a systematic and standardised 3D digital and analytical *chaîne opératoire* method that involves (semi) automatic digital classification and characterisation of the material using quantitative criteria. Moreover, it also seeks to address another gap concerning codification and integration in the process of terminology. Indeed, a few scholars differently approached and debated the coroplastic classification and terminology, but there is still a lack of an agreed and acknowledged language (Nicholls 1952; Muller 1997b; Cantone 2014: 8; Cantone 2015: 102).

1.3 Overview of the Study

Working methodology: archives, museums and labs

The complexity of the research required various information and data from several perspectives. The case study relies on primary (publications of the Ayia Irini excavation) and secondary sources (reviews of the studies and new research) of a variety of types, including archaeological publications, excavation diaries, scholarly articles, drawings, sketches, old photographs, maps and, of course, the artefacts.

I conducted systematic work in Cyprus and Sweden at the museums hosting the Ayia Irini collection and at archives and archaeological libraries holding related materials. The collection at the Medelhavsmuseet proved especially important as it holds the entire archive of the Swedish Cyprus Expedition.

Other institutions and archaeological libraries have material related to the Ayia Irini excavation, the Swedish Cyprus Expedition and any topic related to this research. In addition, I consulted materials at the Lund University Library, the Lund University Historical Museum archive (Gastelyckan), Malmö Konstmuseum, Museum Gustavianum in Uppsala, the Cyprus Museum and its library in Nicosia, the libraries of the Archaeological

Research Unit (ARU) of the University of Cyprus, and the Cyprus American Archaeological Research Institute (CAARI).[37]

The dual nature of this doctorate and the evenly spent time at the two hosting institutions (the Cyprus Institute, Cyprus and Lund University, Sweden) facilitated direct research on the material at the museums hosting the Ayia Irini assemblage and afforded significant opportunities to meet with experts and scholars familiar with Ayia Irini. Personal communications with generous scholars in the archaeological and digital heritage fields contributed to the results of this thesis.

A fundamental aspect of the working methodology consists of the 3D digital acquisition of the archaeological artefacts to create 3D models on which to perform a 3D analysis aimed at replying to the research hypothesis of this dissertation. In addition to the digital data acquisitions, we conducted non-invasive chemical analyses on some artefacts to collect data on the compositions of their materials. All activities and analyses relied on the lab's instruments and facilities of the two doctorate hosting institutions (APAC/STARC labs of the Cyprus Institute and the Department of Archaeology and Ancient History, Lund University). For the 3D geometric analysis, this research benefited from the collaboration with the research group of the Institute for Applied Mathematics and Information Technologies "Enrico Magenes" of the Italian National Research Council in Genova (IMATI–CNR) within the framework of the European project GRAVITATE.

Structure of the thesis

In this introduction, I have stated the aim of the current study and situated it in related fields' literature to highlight its contribution. The thesis comprises five further chapters that fall into three sections.

In the first part, Chapters 2 and 3 frame the case study and establish the research methodology. More precisely, Chapter 2 presents the case study, describing the study subject, namely the small terracotta figurines from the Ayia Irini sanctuary and its excavation. This chapter details essential information about the archaeological context, artefacts, and historical background. Chapter 2 also reviews current knowledge, primary investigations, secondary scholarships, theories and debates, seeking to identify gaps and possible research questions. This literature review leads naturally to a discussion of the usefulness of a fresh examination of the collection using a 3D digital approach.

[37] Some of these institutions have facilities to consult the material online.

Chapter 3 delineates the research methodology based on a 3D digital and analytical approach and provides theoretical and procedural descriptions of the technologies, instruments, and methods used in this study. Reviewing current practices and state-of-the-art technologies is necessary to select the appropriate methods to gather data (document, collect, describe and create) on which to perform analyses for the current study aims. The chapter reports the methodology and the strategy applied for data capture, tested to identify the best solution for the digital acquisition of the materials' data.

The second part examines the application of the method, analysis and results. Chapter 4 presents a literature review to explain the analytical rationale for the study: the choice of the appropriate quantitative analysis' methods and the solutions adopted to test the hypothesis.

The third part of the thesis comprises the interpretative discussion and conclusive remarks. Chapter 5 provides the archaeological interpretation of the results obtained during the experimental section on the case study material and its theorisation. Finally, Chapter 6 focuses on the conclusions, reflections, and evaluations, suggesting future applications for this approach.

2. The Case Study

Cyprus holds a favourable position at the intersection between important cultural directions from and to the Anatolian, Aegean, and Syro-Palestinian Regions (Figure 2.1). The island forms a bridge between these zones: it assimilated and profoundly transformed the influences from the surrounding populations and gave birth to an autonomous tradition. It is the third-largest island of the Mediterranean Sea at 9,251 square kilometres: the populated areas, in every historical period, connect to the physical characteristics of the land and the two major mountain systems, the Kyrenia Mountains[38] in the north and the Troodos Mountains in the central west area. The Troodos Mountain Range runs 175 kilometres from Cape Kormakitis in the west to Cape Ayios Andreas in the east. Although rocky and steep, travellers can move between the central valley and the north coast through mountain passes. The Troodos Mountain Range, which hosts rich and diverse forests and vegetation, occupies the island's centre. The Mesaoria Valley rests between these two ranges. This valley's suitability for hunting and agriculture gave rise to dozens of ancient settlements (Graziadio 1998: 9-10).

The village of Ayia Irini lies on the island's northwest coast, between the ancient cities of Soloi and Lapithos, on a rocky plateau between the alluvial valley of Morphou and the foothills of the Kyrenia Mountains, which run towards Cape Kormakitis. The Swedish Cyprus Expedition (SCE) described the area as sterile and isolated, covered by a thin layer of soil and scarce vegetation, partly cultivated, and partly covered by pines. The Ayia Irini sanctuary sits alongside the villages of Myrtou and Diorios on a plateau that slopes down the sea (Gjerstad et al. 1935: 642-643).

[38] Local tradition gives the term Pentadaktylos to the Kyrenia Mountains due to a rocky formation that resembles five fingers.

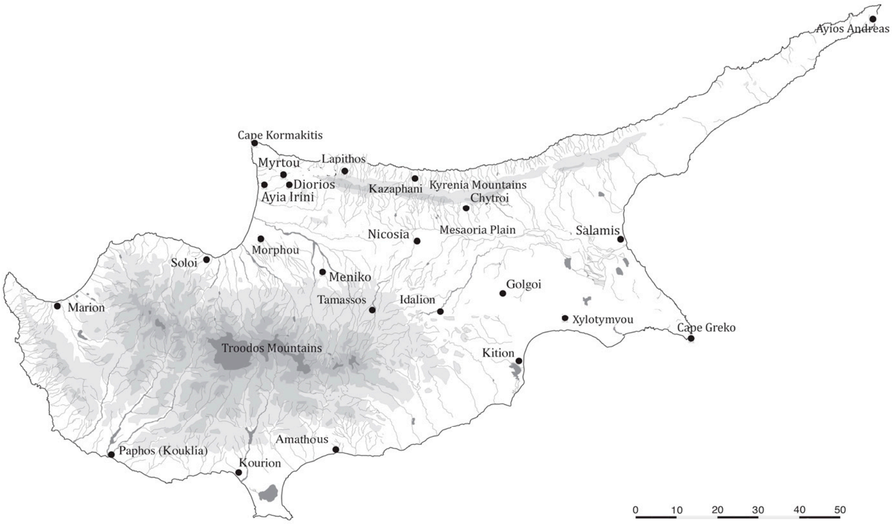

Figure 2.1
Ayia Irini and its geographical position.

2.1 The Swedish Cyprus Expedition and Ayia Irini

The SCE, which operated from 1927 to 1931, played a significant role in the island's archaeological history because the expedition's archaeologists used modern methods to excavate many sites properly. By doing so, they contributed to the documentation of ancient Cyprus (Houby-Nielsen 2003: 4-9; Winbladh 2003b: 13; Göransson 2012: 399). The late Vassos Karageorghis lauded their efforts, writing that the SCE "laid the foundation for the study of all aspects of Cypriote archaeology" (Karageorghis 2009: 7).

Surprisingly, the archaeological investigation of the island was not part of Gjerstad's original plan. In his book, *Ages and Days in Cyprus* (Gjerstad 1980), Gjerstad explains that in March 1922, Axel W. Persson, Professor of Classical Archaeology at the University of Uppsala, travelled to Asine, Greece for archaeological excavation where he met the famous collector of antiquities and Swedish Consul in Cyprus, Lukas Pierides. While travelling together on the Orient Express, Persson lent money to Pierides for a visa. Pierides later invited Persson to excavate in Cyprus and gifted the Swedish Crown Prince with an ancient Cypriot artefact. Persson gave the job to his most brilliant student, Einar Gjerstad, who first visited Cyprus in 1923-24 and completed his dissertation “Studies on Prehistoric Cyprus” in February 1926. A year later, SCE began its expedition thanks to private donors and the Swedish Crown's political support.

Four people took part in the Swedish Cyprus Expedition. The expedition leader Einar Gjerstad (1897-1988) collaborated with the archaeologists Erik Sjöqvist (1903-1975) and Alfred Westholm (1904-1996) and the architect John Lindros (1898-1961). Sjöqvist and Westholm oversaw fieldwork, while Gjerstad and Lindros travelled from one excavation to another. The former directed operations, while the latter produced plans and photographs for documentation. This system enabled the SCE to simultaneously excavate multiple sites, shedding light on various settlements, tombs and sanctuaries ranging from Neolithic to Roman (Göransson 2012:400).

In 1929, Sjöqvist excavated the site of Ayia Irini. The excavation, initially not included in the plan of the Swedish expedition, started in November after the village’s priest, Papa Prokopios, happened upon the upper part of a terracotta statue of the sixth-century BC in his fields. The SCE surveyed his fields and located an intact cult area (Gjerstad et al. 1935:642; Bourogiannis 2013:37). Recognising the importance of the site, Gjerstad and his team began to focus most of their resources on Ayia Irini.[39]

The work of the SCE at Ayia Irini led to the discovery of additional sites in the surrounding area. For example, during the 1970 and 1973 seasons, Italian archaeologists excavated a necropolis, dating from the Geometric and Archaic periods, in the area called *Paleokastro* (Pecorella 1977:1-298; Rocchetti 1978:1-120; Pecorella & Rocchetti 1985:193-194). During the same period, a team explored a possible ancient citadel identified with the harbour of ancient Melabron (Quilici Gigli 1971; Quilici & Quilici Gigli 1975).[40] These finds confirm the continuity of use of the area and the presence of other settlements in different periods.

As a result of the Turkish invasion of northern Cyprus in 1974, all the archaeological missions interrupted their research; currently, Ayia Irini is inaccessible to archaeologists (Bourogiannis 2013:37; Bourogiannis 2015). As a result, recent scholarship focuses on reviewing published data and

[39] Similarly, later scholars dedicated their interest on the site and its material (Gjerstad et al. 1935; Gjerstad 1936; Ikosi 1991:vol. 26-27, 33-84; Ikosi 1992: 267-309; Winbladh 2003b; Fourrier 2007: 89-92; Papantoniou 2012a: 299-301).

[40] For a complete bibliography of the research on the area and on discoveries possibly related to the area, see Orsingher 2016: 313-324; Houby-Nielsen 2016: 105, 114.

unpublished excavation records and applying technologies to extant artefacts.[41]

The site of Ayia Irini consists of a rustic *temenos*, with small buildings surrounding an open court (Figure 2.2.). A limestone altar with an oval stone on top stands in a court located near an enclosure that Gjerstad identified as the location of a sacred tree (Gjerstad et al. 1935: 672; Gjerstad 1948: 455)[42] Around the altar, in a semi-circular position, the SCE found more than 2,000 terracottas, votive figurines and statues of various sizes and forms: humans, animals, bulls, chariots, and minotaurs (Figure 2.3). These finds imply that cult followers offered the statues to a warfare god as they are almost exclusively armed male figures.[43] The human figures range from approximately 20 to 200 centimetres. Vassos Karageorghis argues that some terracottas might represent specific worshippers because they include unique facial characteristics (Karageorghis 1995: xi). Sabine Fourrier adds that the collection may represent a variety of types linking to specific workshops or creative centres on the island. Fourrier, based on stylistic similarities, suggests sub-groups of production (or imitation) that she connects to the organisation of the Iron Age city-kingdoms. Specifically, she places the analysed Small Human Idols from Ayia Irini into various stylistic groups related to the respective zones of cultural influences, for example, Soloi, Idalion, Kition or Lapithos (Fourrier 2007:89-92, 127-132).

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[41] For a complete bibliography of recent scholarship, see: Bourogiannis & Mühlenbock 2016; Houby-Nielsen 2016: 105-117; Orsingher 2016: 313-324; Bourogiannis 2016: 91-103; Colosimo 2015; Mühlenbock & Brorsson 2016: 299-311; Vassallo 2015: 227-232; Vassallo 2017: 203-216.

[42] Gjerstad et al. (1935: 672) and Sjöqvist (1933: 349-350), on the basis of comparison with Minoan seals, agree that Room XII and XIII were enclosures of sacred trees.

[43] Scholars also propose the attribution to a fertility god because of the presence of numerous bulls, which in antiquity are usually symbol of fertility in its broadest meaning (nature, agriculture, wealth, power).

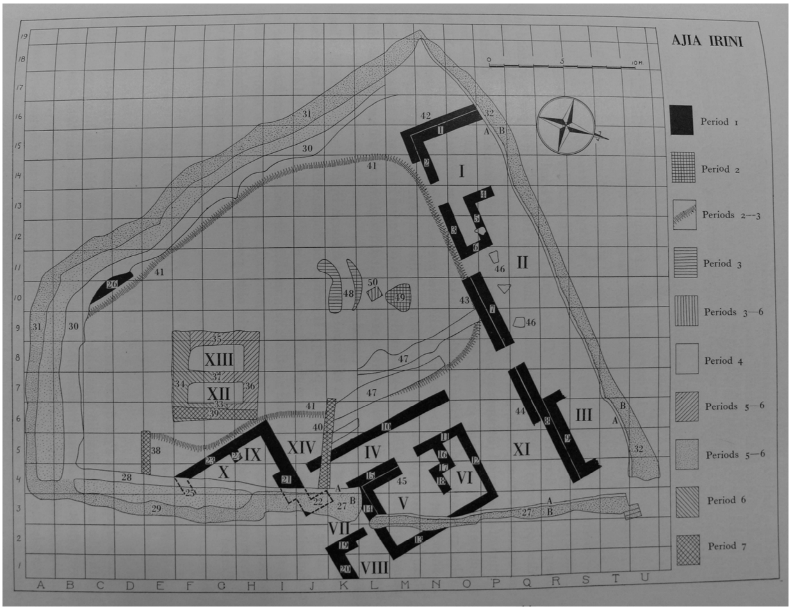

Figure 2.2.
Analytical architectural plan of the Ayia Irini sanctuary (Gjerstad et al. 1935: 665, fig. 263).

Figure 2.3
General view of the sculptures around the altar (MM C01801, Swedish Cyprus Expedition archive).

Although Gjerstad and his team contributed significantly to the history of Cyprus, as modern archaeologists, we have a variety of tools and decades of scholarship that shed new light on the discoveries in the region. With this hindsight, we can identify the limits of past research; in the case of Ayia Irini, modern scholars must contend with the following: the reliance of past research on qualitative observation, a complicated stratigraphy, and the division of the collection between Sweden and Cyprus.

First, much of the scholarship of the past relies on subjective methods, including visual qualitative observation. In the early years, archaeologists and art historians relied on "style" to identify common characteristics between artefacts. Of course, it is impossible to avoid bias in such a subjective method. For this reason, in his study *Religion and Social Transformation in Cyprus* (2012), Giorgos Papantoniou underlines the need to be "cautious and context-oriented" when applying stylistic analyses. Archaeologists, he argues, should not necessarily interpret stylistic patterns as a reflection of cultural or social identities since the patterns may not correspond only to regional styles (Papantoniou 2012b: 98).

Second, differing documentation and opinions about the stratigraphy compound the difficulties caused by categories defined solely by visual criteria. Stratigraphy presents difficulties for modern scholars interested in Ayia Irini. The SCE identified seven periods of use at the sanctuary, positing that cult worship started at Ayia Irini at the end of the Late Cypriot III and survived until the last quarter of the Cypro-Archaic II period – this makes Ayia Irini the only known example of a supposedly unbroken archaeological sequence of strata in Cyprus. Based on the archaeological record, the SCE asserts the continuity of worship at Ayia Irini from the 12th to the 6th century BC. Notably, the SCE identified periods 4 to 6 (ca. 700-500 BC) as the most important at the site. According to Sjöqvist and Gjerstad, a local stream flooded the area several times. After a flood around 500 BC, worshippers abandoned the *temenos* but later returned in the 1st century BC. Although Sjöqvist and Gjerstad disagree on some stratigraphic details, they agree that the layers and the position of the archaeological materials found *in situ* support these floods (Gjerstad et al. 1935). Difficulties in reading the site stratigraphy will be addressed further in this chapter.

Third, the artefacts of Ayia Irini are currently spread across five museums in Sweden and Cyprus due to the legislation of the British Colonial Government in 1931.[44] At the end of the Swedish expedition, the colonial

[44] The British maintained the Ottoman law on Antiquity of 1874 and enacted the new Antiquities Law of 1905. Both the laws allowed foreign missions to bring part of the finds to their countries. During that historical frame, it is not rare that western European

administration allowed the archaeologists to bring part of the total Cypriot excavated finds to their country. The SCE sent thousands of items from different Cypriot excavations to Sweden (Figure 2.4). Gjerstad states that:

> As a principle of division it was laid down that the find-units, i.e. tomb-groups and deposits, were not to be split up, but were to accrue as a whole either to Cyprus or Sweden, and […] that Sweden was to receive a representative series of finds from all epochs and of all kinds of objects (Gjerstad 1932: 5).

As a result, Sweden received approximately two-thirds of the nearly 18,000 artefacts, including pottery, faience, bronze, iron, silver and gold objects, and stone and terracotta sculptures. Furthermore, Sweden received "all the sherd-material of any scientific value" (Gjerstad 1932: 5). In practical terms, the SCE sent approximately 12,000 items packed into 771 boxes from Nicosia to Famagusta and then on to Stockholm. Thousands of sherds of lesser significance further enriched this considerable number of objects, including diagnostic pottery fragments (Karageorghis 2009: 9-10; Göransson 2012: 411).

Figure 2.4
The transfer of the archaeological material from Cyprus (Famagusta harbour) to Sweden in March 1931 (Photo: The Swedish Cyprus Expedition, MM neg. C06267).

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countries collected and disposed of antiquities coming from the places under their jurisdictions (Bonato et al. 2007).

According to records from the period, the Swedish archaeologists divided the collection to allow scholars to study the material either in Cyprus or Sweden. Significantly, the Swedes chose to leave unique pieces in Cyprus. Due to their artistic similarity, the terracotta statuettes ranked low in the "uniqueness" hierarchy, and the team divided them between Cyprus and Sweden.[45] As a result, Ayia Irini's substantial collection cannot be studied in its entirety – instead, scholars must visit the five museums and archives in two countries (Figure 2.5).

Although the site of Ayia Irini holds a prominent position in the history of culture and heritage of Cyprus, its study is not without difficulties. Relying on a past excavation and documentation that is almost one hundred years old leads to confusion and discrepancies that are sometimes impossible to resolve. Modern technologies and quantitative methods such as 3D geometric analysis and non-invasive physico-chemical investigations allow us to re-examine extensive archaeological collections, and in the case of Ayia Irini, digitally reunite artefacts that have been separated for a century for a holistic re-assessment.

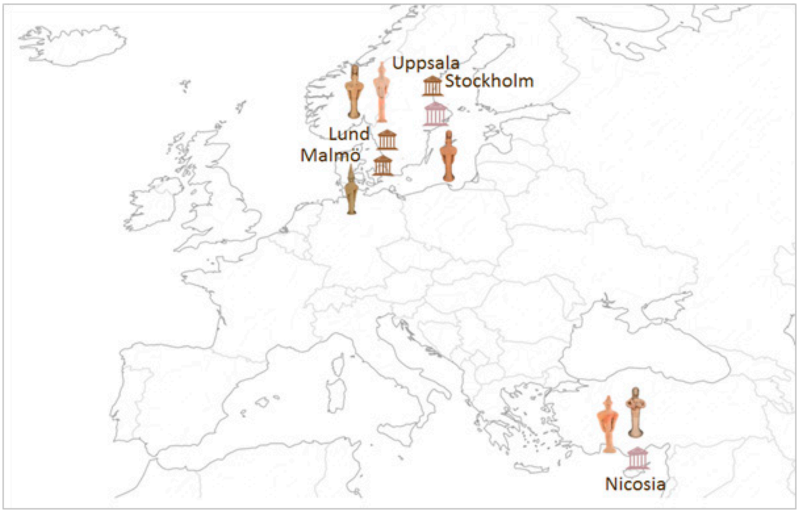

Figure 2.5
Geographic dispersion of the Ayia Irini collection (Vassallo©).

[45] The Medelhavsmuseet in Stockholm exhibits its part of the collection and houses archives of the excavation including diaries, original plans, drawings, and thousands of photographic negatives.

2.2 The open-air sanctuary of Ayia Irini

Historical context

During the 1st millennium BC, the Cypriot landscape was politically organised into independent kingdoms ruled by cities, which also contributed to the island's economic growth. The Cypro-Archaic period is particularly important for establishing the territories and the power of the city-kingdoms. In this period, the consolidation of the kingdoms gave birth to a rapid increase in the number of extra-urban sanctuaries, especially in the Mesaoria valley, where important city-kingdoms have their boundaries and the sanctuary of Ayia Irini lays (Papantoniou 2012: 287).

The Ayia Irini site is located in the north-west area of the island, positioned in a zone between Lapithos and Soloi, two sites generally identified as city-kingdoms. Based on that location, scholars alternatively associated Ayia Irini either with the territory pertaining to Lapithos (Mavrogiannis 1999: 100; Ulbrich 2008: 376, 378) or Soloi (Fourrier 2007: 89-92, 104-106). A recent study[46] on the island's Late Roman landscape, through the integration of *Cost Surface* (CSA[47]) and *Least Cost Paths* analysis (LPC[48]) within Geographical Information Systems (GIS), underlines the position of the Ayia Irini sanctuary as perfectly equidistant between the two city-kingdoms of Soloi and Lapithos and suggests that the sanctuary most probably served both areas (Kyriakou 2011: 289-298).[49]. Therefore,

[46] The study regards the GIS simulation for decoding rural landscapes in antiquity and the rural environment of Late Roman towns in Cyprus, examining the territorial boundaries, the distribution of the settlements, and their hierarchies and inter-relations. It is a simulation that aims at integrating the environmental, economic, and cognitive aspects of the rural landscape in antiquity.

[47] Cost Surface Analysis (CSA) relies "on a main axis, defining the accessibility of different locations and is rooted on traditional site catchment analysis" (van Leusen 2002: 6-4). "In general terms the result of a map produced by CSA is a map that indicates those parts of the landscape which are most easily accessible from a site and those which are not" (Kyriakou 2011: 294).

[48] Least-cost path analysis (LCPA) is a distance analysis tool within GIS that uses the least cost path or the path between two locations that costs the least to those travelling along it to determine the most cost-effective route between a source and a destination. Cost can be a function of time, distance or other criteria defined by the user.

[49] The study employs GIS to understand the connection between the foundation of sanctuaries and the power's establishment of the city-kingdoms during the Cypro-Archaic period. The analysis identifies the extension of the territories of each (known) town of the island, considering the landscape's environmental, economic, and social variables. As the author states, "it must be underlined that the archaeological remains will be incorporated in the

Ayia Irini is considered a "frontier zone" between city-kingdoms during Cyprus's political and geographical transformation of the Late Bronze and Early Iron Age. Scholars believe that independent kingdoms around the leadership of central cities ruled the island for a long time, a situation that contributed to a period of prosperity due to the commercial relations between the sovereigns and their Near East counterparts (Fourrier 2007; Papantoniou 2012a: 299-300; Fourrier 2013: 103-122; Iacovou 2013a: 15-47).[50]

Due to the scarcity of literary sources, Maria Iacovou and others still debate the origin, geographical boundaries, and size of Cypriot city-kingdoms. The extant written sources that mention Cypriot city-kingdoms are Assyrian royal inscriptions that date from the Iron Age. According to these inscriptions, Cypriot Kings submitted to the Assyrian Empire: seven kings to Sargon II in 707 BC and ten to Esarhaddon in 673/2 BC. Similarly, Hellenistic sources indicate that Ptolemy I Soter suppressed the city-kingdoms of Cyprus and annexed them to the kingdom of Ptolemaic Egypt between 310-294 BC. These documents establish the existence of Cypriot city-kingdoms in the Archaic period; however, they are devoid of any substantive information indicating foundation time, size, boundaries, and composition (Iacovou 2004: 263-264, 268, 270-271; Gjerstad 1948: 449; Iacovou 2002: 80-85; Iacovou 2013a: 15-16). Scholars believe that extra-urban sanctuaries had a key role in forming the Cypro-Archaic and Cypro-Classical city-kingdoms. Sanctuaries started to appear in the countryside during the end of the Cypro-Geometric period, growing larger during the Cypro-Archaic, along with the maximum power of the Cypriot polities. The position of these extra-urban sanctuaries may indicate changes in socio-political boundaries, shifts in communication routes between the city-kingdoms, or new settlements (Papantoniou et al. 2014: 70-71).[51] According to Fourrier, during the Archaic period of the city-kingdoms, Cyprus participated in the expansion of craft production, including coroplastic, sculpture, and pottery. As extra-urban sanctuaries proliferated and the

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suggested territorial model. Such material derives from the archaeological field surveys, where sites locations can be found but also the main source is the Roman road network and the milestones, which provide a well-documented archaeological record for the coastal territorial limits of the Roman towns of Cyprus, and finally, the literary sources" (Kyriakou 2011: 289).

[50] The relations with the Near East also influenced art and techniques (Winbladh 2010).

[51] Further analysis on the inter-visibility between the known sanctuaries sites of the island and other centres could provide further information on their relations, the choice of the location of these sanctuaries, their function, meaning, and possibly to identify new sites (Papantoniou 2013: 73, 74).

countryside of Cyprus grew denser, craft production boomed. The new political setting brought along an affirmation of different regional cultural identities, which reflect the stylistic features of the coroplastic found at Ayia Irini (Fourrier 2007: 13-14).

The position of Ayia Irini makes the sanctuary important in this geo-political landscape, creating a connection between extra-urban sacred space and the formation of political and cultural identities. The Ayia Irini sanctuary assumes a particular significance and might have represented a meeting space between those cultural and political identities, where the votives, beyond having a religious meaning, also represented a symbol of power and control on the territory (Papantoniou & Bouogiannis 2018).

The stratigraphy of Ayia Irini

Ayia Irini is the most complete and well-preserved sanctuary site of Early Archaic Cyprus. Alongside the extraordinary finds, which give valuable information about the cult practices of their time, the relevance of this site derives from its published stratigraphy and the interpretation of Einar Gjerstad, the expedition leader and author of the SCE's reports.[52] The site's stratigraphy is the most troublesome aspect of the site, with several scholars, including Georgios Bourogiannis, Sabine Fourrier and Sanne Houby-Nielsen offering revisions of the findings of the SCE.

Erik Sjöqvist excavated the sanctuary, but Einar Gjerstad, the team leader, interpreted and published the data. Bourogiannis and Houby-Nielsen speculate that this situation might have caused an unclear interpretation of the site's stratigraphy, which they interpret as a sequence of various floods and layers of alluvial sand with cases of disturbance among them (Bourogiannis 2013: 37-41; Bourogiannis 2016: 92-93; Houby-Nielsen 2015; Houby-Nielsen 2016: 111).

According to Gjerstad, four floods inundated the site and the statues (Gjerstad et al. 1935: 663-664), producing layers of alluvial sand between successive periods (Table 2.1). Gjerstad used this fortunate stratigraphy to establish a chronological sequence where he placed the large-scale terracotta statues. Gjerstad matched the stratigraphy with his stylistic observations of

[52] The first SCE publication of the excavation dates to 1935, years after the end of the expedition in Cyprus. In 1948 and 1963, Gjerstad published some revisions and new interpretations, focusing on large-scale sculptures (Gjerstad 1948; Gjerstad 1963).

the statues, creating a paradigmatic schema used by scholars to date sculpture, as well as other artefacts found across Cyprus.[53]

Gjerstad's 1935 publication explained the stratigraphy accompanied by eighteen section drawings of the excavated area (Gjerstad et al. 1935: 653-663). He identified twelve layers associated with seven periods at the site.[54] The life span of the sanctuary covers the first six periods, which Gjerstad dated from Late Cypriot III (ca. 1200 BC) to the end of the Cypriot Archaic II period (ca. 500 BC). After this date, the site was abandoned. Gjerstad found no evidence of Cypro-Classical use. But there is archaeological evidence of a short return to the area in the Hellenistic period.[55] The main, regular use of the site is between ca. 650 and 550 BC. Table 2.2 shows the link between the historical chronology of the site -the Gjerstad's Periods- with the cultural phases of Cyprus and their periodisation. These periods also reflect in the changes that SCE identified in the architecture of the sanctuary (Figure 2.2.):

- a Late Cypriot III Bronze Age complex made of rectilinear structures enclosing a rectangular courtyard (Period 1);
- a Cypro-Geometric open-air *temenos* of irregular shape, surrounded by a *peribolos* wall of red earth (Period 2-3), replaced the previous complex;
- two subsequent rubble altars, one in Period 2 (ca. 1050-800 BC), replaced in Period 3 (ca. 800-650 BC) by a new one that remained in use until the end of the Cypro-Archaic period.

[53] Although Gjerstad did not apply his stylistic/chronological schema to the small-scale terracotta figurines, it is crucial to understand how they fit into this context, since it is one that underpins all historical and contemporary study of the Ayia Irini finds.

[54] The SCE did not identify the twelve layers in the whole area excavated. Gjerstad confirmed his interpretation of the Ayia Irini stratigraphy in the supplementary notes to the SCE publication (Gjerstad 1963: 4).

[55] Gjerstad informs about a Hellenistic presence on the other side of the valley towards the sea that maybe relates to the reuse of the site in the Hellenistic period (Gjerstad et al. 1935: 643).

Table 2.1
Dates of the Ayia Irini layers and floods as summarised by Bourogiannis (2013: 39, Tab.1).

Layers	Gjerstad's interpretation	Suggested absolute dates
1	Topsoil	
2	Flood after Period 7	After the late 1st century BC
4	Flood between Periods 6 and 7	510-500 BC
6	Flood between Periods 5 and 6	ca. 540 BC
8	Flood between Periods 4 and 5	600/560 BC

Table 2.2
Chronological table showing the chronology of the Ayia Irini site linked with the Cypriot cultural phases and their dates. The coloured cells correspond to the period designated as the most important for the sanctuary, according to Gjerstad. The reference for the cultural phases is the one proposed by Nys & Åström (2005: 4).

	Cultural phases	Conventional dates	Periods
Late Bronze Age	Late Cypriot III	1200-1050 BC	Period 1
Iron Age	Cypro-Geometric I	1050-950 BC	Period 2
	Cypro-Geometric II	950-900 BC	Period 3
	Cypro-Geometric III	900/850-750 BC	Period 3
Archaic period	Cypro-Archaic I	750-600 BC	Period 3/4
	Cypro-Archaic II	600-475 BC	Period 4/5/6
Classical period	Cypro-Classical I (hiatus)	475-400 BC	
	Cypro-Classical II (hiatus)	400-310/300 BC	
Hellenistic period	Hellenistic I (hiatus)	310/300-150 BC	
	Hellenistic II	150-30 BC	Period 7

In recent years, however, scholars have questioned Gjerstad's stratigraphic sequence and his unbroken use of the sanctuary between the Late Bronze Age and the Early Iron Age and revisited his conclusions – some confirming and some deconstructing them. For example, Georgios Bourogiannis' (2016: 93) study establishes new horizons based on his study of the unpublished diagnostic sherd material kept at the Medelhavsmuseet.

Bourogiannis' systematic study debates Gjerstad's conclusion on the sanctuary's early days (Bourogiannis 2016: 91-103). Some observations are important for the site's early history, which Bourogiannis' research pushes further back into the Bronze Age (Middle Cypriot III and Late Cypriot IA).

Even if we cannot confirm the cultic character of this material, we may note that it matches the earliest pottery found at the Ayia Irini *Paleokastro* burials, linking the site to the neighbouring cultural landscape. Bourogiannis attributes the increase in pottery during the Late Cypriot period to the start of the cult of Ayia Irini. The material evidence indicates an earlier, Late Cypriot II chronology rather than the Late Cypriot III chronology suggested by Gjerstad. Unfortunately, the mixed stratigraphy of the site obscures the site's Early Iron Age cultic continuity. The Cypro-Geometric I and II phases are especially difficult to restore. Bourogiannis dates most of the items between the Cypro-Geometric III and the early phases of the Cypro-Archaic II period, confirming Gjerstad's proposal of being the most important phase of the sanctuary (Bourogiannis 2016: 98). Contrarily, he identified a few Hellenistic fragments, and therefore he could not prove the reuse of the sanctuary during this period.

Bourogiannis' analysis reveals a great abundance of Cypro-Archaic I fragments. It confirms Gjerstad's identification of the 7th and 6th centuries BC as the most important phases of the sanctuary. That is the period when the Small Human Statuettes become relevant.[56] Furthermore, the pottery confirms the rural Cypriot character of the sanctuary. Indeed, the analysis attests to some Aegean imports in the Late Bronze Age, but these decreased during later phases. Similarly, true Phoenician imports are rare, but imitations made in Cypriot clay are more frequent. The remains confirm the Cypriot character of the sanctuary with few imports – and Cypriot imitations of foreign productions. Most important is that the ceramic fragments examined show a mix of the archaeological layers throughout the excavated area: even Bronze Age material was found mixed with Cypro-Geometric and Cypro-Archaic fragments. That means that Bourogiannis' analysis of the pottery does not confirm the ideal stratigraphic sequence proposed by Gjerstad (Bourogiannis 2016: 98, 100).

Like Bourogiannis, Fourrier questions the chronological sequence proposed by Gjerstad. In particular, she probes Gjerstad's alleged unbroken

[56] The discovery at the Heraion of Samos of the richest finds of Cypriot terracotta figurines in the East Aegean, contributed to further dating of the Cypriot coroplastic (cf. Schmidt 1968). The stratigraphy of the Heraion of Samos, a chronological range from circa 720 to 560 BC, attributes this kind of production to the same period (Ikosi 1993: 76). New stratigraphic evidence from the Aphrodite sanctuary at Miletos attested Cypriot figurines in a *bothros* closed in ca. 630 BC. Together with the previous information about the known stratigraphy of the Heraion of Samos, this discovery gives proves that these kinds of imports started around 670 BC, initially with few of them, then with a much larger quantitative in a very short period between circa 650/640 and 630 BC (Henke 2017: 274).

continuity of cult from the Bronze Age to the Early Iron Age (Gjerstad et al. 1935: 817; Fourrier 2007: 89, 104-106). Fourrier points out an inconsistency in stratigraphic methodology as Gjerstad supposedly considers the earlier rather than the later pottery finds within a layer (Fourrier 2007:89, 104-106). Similarly, Ikosi (Ikosi 1991-92: 82 n. 1) and Windbladh (Windbladh 2003: 152-153) raise the question of making statements about the chronology but without new contribution to the detailed assessment of Gjerstad's dating methods. Papantoniou underlines that attribution to the Cypro-Geometric III of the first Iron Age phase of the sanctuary would fit within a more general scheme on the island. That is the period, connected to the rise of the Iron Age polities, of establishing other extra-urban sanctuaries in Cyprus. According to Papantoniou, the sanctuary's most important period of Ayia Irini is the Late Cypro-Geometric and Early Cypro-Archaic periods, corresponding to the period when the city-kingdoms held the most power (Papantoniou 2012a: 301; Papantoniou 2013: 46).

Sanne Houby-Nielsen's new research into the unpublished field documentation relating to Ayia Irini in the archive of the Medelhavsmuseet has revealed a possible "phantom" existence of Gjerstad's flood stratigraphy (Houby-Nielsen 2015). She has, for the first time, combined the documentation produced on-site by the architect Lindros and the field director Sjöqvist (Sjöqvist 1933:312) with information gained from the private letters by the archaeologist Alfred Westholm (Westholm 1994:7-21; Westholm 1996). By comparing field documentation and published results, Houby-Nielsen observes different views by Gjerstad and Sjöqvist regarding flood stratigraphy. Sjöqvist, who excavated the site and the statues, identifies only two floods: one before the worshippers placed the figures and another after; he, therefore, documents the votives as one assemblage, not disturbed by intermediary floods. Like Sjöqvist, Lindros, who arrived on the site after excavating the votive figures, documents them as one assemblage. Gjerstad explains the stratification and periods as a consequence of four floods. In his view, worshippers returned to the site after every flood to find votives half-covered by debris, which they left *in situ*; they then added new votives, creating new floor levels connected with different periods. Unfortunately, this assertion is difficult to prove, as Houby-Nielsen points out in her article. Indeed, although SCE published numerous section plans, only some of the originals are conserved in the archives. Nevertheless, after comparing the survived originals, Houby-Nielsen identified errors in the published plans and concerning some sections (e.g., features' lack or change, publication in reverse).

Houby-Nielsen argues that the published sections offer no sound evidence of floods. She speculates that contemporary finds in Mesopotamia influenced

Gjerstad's interpretation: at Ur, British archaeologists found sterile alluvial layers, interpreted as the "Great Flood" in the Book of Genesis. In the end, Houby-Nielsen debates much of Gjerstad's stratigraphy, arguing that all the votives' levels, wisely recorded by Sjöqvist, do not represent different deposition dates on different stratigraphic floors. However, they are due to the irregularity of the terrain and conscious choices, placing the statues according to specific arrangements including ethnicity, status, dimension (Houby- Nielsen 2016: 111-112).

In her work, Houby-Nielsen relied on archival sources in which she found inconsistencies between original and published drawings of the site beyond the discrepancies in the flood stratigraphy. Based on this work, she achieved some conclusions on further aspects of the stratigraphy: 1. Foundations embellished; 2. Red earth enclosure wall; 3. Presence of circular paved floors.

First, she found that the SCE "embellished" the foundations of the Bronze Age buildings in published accounts. Relying on earlier drawings and excavation photos, she concludes that the corners of the cult building, as defined by Sjöqvist (1933), were missing, and the walls on the three sides were not well preserved.

Second, she concludes that the red earth layer of the open-air *temenos* may be the remains of sun-dried clay walls related to an earlier Bronze Age building that collapsed. After comparing published accounts of the nearby sanctuary of Myrtou Pigadhes (du Plat Taylor 1957: 115), she speculates that the walls were later reused as the foundation of the *temenos* wall. This observation supports Gjerstad's view of the red earth as an enclosure wall (Gjerstad et al. 1935: 649-650, 671).[57] Third, Houby-Nielsen makes a convincing argument based on a close study of archival documents, published reports, plans, sections, and related contemporary finds (Houby-Nielsen 2016: 110-112). She posits that a sequence of paved circular floors or platforms for ritual displays of votives and pottery connect with the "geometric" and "archaic" sanctuary (Figure 2.6). Specifically, she noticed that Sjöqvist and Gjerstad identified and attributed a triangular paved area to a "geometric" rubble altar, and that Lindros' original drawing, with a written annotation "early archaic", demonstrates that the triangular floor was part of a larger pavement (cfr. Figure 2.2. and Figure 2.7). A circular stone with man-made holes grabbed Houby-Nielsen's attention east of the triangular area. Sjöqvist reports the circular feature in his plan and interprets it as a libation stone (Sjöqvist 1933: 324), Gjerstad reports only half of the stone

[57] Sjöqvist interpreted the red earth layer as a man-made floor to cover the previous Bronze Age ruins (Sjöqvist 1933: 323-324).

with no connection with other structures, while Lindros' plan shows the entire stone that is partly included in a larger circular paved floor.[58]

Moreover, she argues that the semi-circular Walls 48 A-B in the SCE publication probably formed overlapping floors. The original Lindros' plan suggests the presence of curved paving stones, but these were not addressed or published by Sjöqvist or Gjerstad. She interprets elements labelled "odd" or "secondary" by Sjöqvist and Gjerstad as part of a series of circular paving stones. She notes examples where elements of the original Lindros' drawings are undervalued and thus deleted from published plans. For example, Gjerstad viewed structures 47 A-C as elements used to secure wooden poles for a roof, and he adjusted their shape to confirm his hypothesis, while Sjöqvist removed them from his plans.

Houby-Nielsen's investigation destabilises Gjerstad's assertion on different aspects of the site's stratigraphy. However, at this stage, we cannot confirm or reject all the hypotheses mentioned above. The proposals provide interesting hints to further investigate through a quantitative approach. For instance, a spatial analysis approach through Geographical Information Systems (GIS) can help to assess the different opinions, possibly solving issues of the setting of the statuettes and stratigraphy.

[58] Houby-Nielsen interprets the broken circular stone as a grinding stone for minerals because of the discovery of bronze figurines nearby and the comparison with a similar one found in a Spanish Phoenician mining settlement (Houby-Nielsen 2016: 110; Aranegui 2000: 237).

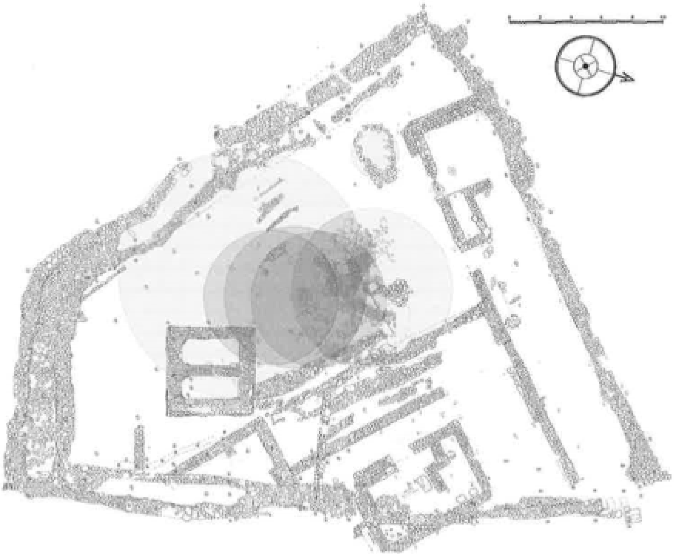

Figure 2.6
Inked re-drawing after J. Lindros´ draft stone-by-stone plan in pencil (1 : 10) in the archive of the Medelhavsmuseet shown together with a suggested reconstruction of stone platforms and together with the distribution of finds drawn by J. Lindros (in Gjerstad et al 1935, 642-643, folded sheet), by S. Houby-Nielsen (after SIMA PB 184, 2016, 109 Fig. 1). Copyright S. Houby-Nielsen.

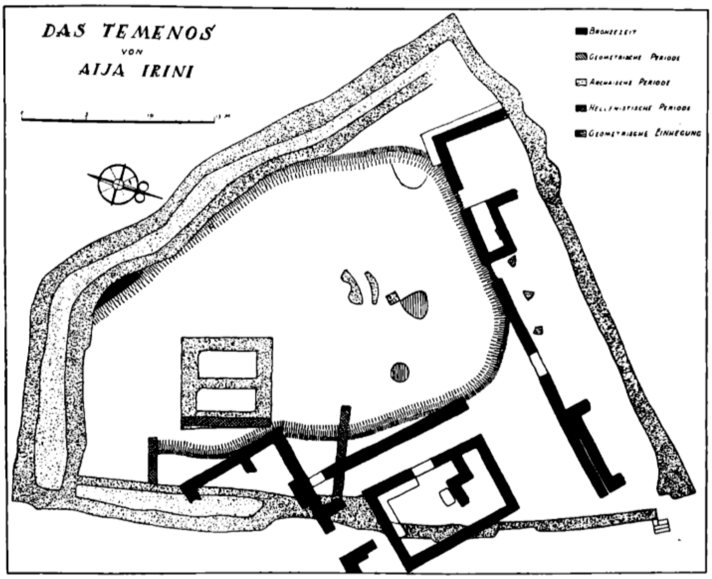

Figure 2.7
Plan of the Ayia Irini sanctuary by Sjöqvist (1933: 312, fig. 3).

2.3 The collection(s) of Ayia Irini

Unfortunately, Ayia Irini lacks any epigraphic evidence. So, we must rely on the material evidence and surrounding context to understand the site's meaning and use. Most of the terracottas from Ayia Irini are male figures of small, medium, and large sizes, including standing forward-facing warriors and priests wearing helmets or conical caps. They generally hold military, votive or musical objects such as weapons, sacrificial animals, bull masks, flutes, and tambourines. The characteristics of these *ex-votos* imply the presence of a warfare deity, as suggested by Gjerstad; Papantoniou's work on extra-urban sanctuaries in Cyprus supports this conclusion (Gjerstad et al. 1935:642-674; Papantoniou 2012b). Bourogiannis supports the role of the Ayia Irini sanctuary as a "frontier zone" and proposes that this explains the offering of votives connected with symbols of power: armed figures, chariots, charioteers, and centaurs compose the majority of the Cypro-Archaic I and II terracottas (Bourogiannis 2016:92). Based on these elements, many researchers posit the existence of a male deity at Ayia Irini, probably connected with fertility and agriculture (Beer 2009:36-49; Winbladh 2003a:152). The animals and instruments carried by the figurines imply that sacrifices, sacred banquets, music, and dances accompanied the cult (Winbladh 2003a: 162; Papantoniou 2012b: 278).[59]

Unfortunately, very few inscriptions attest to the deities worshipped in the ancient sanctuaries of Cyprus. However, based on the few extant epigraphs and the associated finds, Anja Ulbrich[60] connects female votives with female deities, male votives with male deities, and mixed votives with divine

[59] For instance, a terracotta statuette of a human wearing a bull mask (A.I. 809) suggests the presence of rituals at the sanctuary.

[60] Ulbrich's study was born from the consideration that a complete vision of the religious life of Cyprus was very vague without an in-depth investigation of the more than 200 sanctuaries attested. The author analyses the literary, epigraphic, iconographic and archaeological data available on Cypriot sanctuaries, between 750 and 310 BC. She divides the shrines according to the topographical classification and the state of the art on the political geography of the city-kingdoms and territories' borders: Amathous, Chytroi, Golgoi, Idalion, Keryneia, Kition, Kourion, Lapithos, Ledroi/Ledrai/Ledra, Marion, Palaepaphos and Nea Paphos, Salamis, Karpass-Halbinsel/Karpasia?, Achna-Region, Soloi and Vouni, Tamassos. Moreover, Ulbrich subdivides the shrines into topographical-functional categories: urban, sub-urban or extramural, peri-urban or extra-urban, and territory sanctuaries. Max Ohnefalsch-Richter had some intuitions on these relationships (Ohnefalsch-Richter 1893) but it is only after a century that Ulbrich formalises and expands the approach.

couples (Ulbrich 2008; Ulbrich 2012: 101).[61] These correlations further support the attribution of the cult at Ayia Irini to a male god.

Related to that, Fourrier underlines that the places of those sanctuaries and their votives (presence of female or male statuettes) demonstrate a distribution from Cape Greko to Xylotymvou, the southern part of the Salamis territory, mainly of a feminine divinity later associated with Artemis; while from Meniko to Golgoi, in the central area of the Idalian Mesaoria, the sanctuaries are dedicated to a male god associated with war and rural life (sometimes represented in the form of Zeus-Ammon, Herakles-Melqart, Pan, or Apollo). Generally, it is possible to assume that sanctuaries, either urban or extra-urban, had an important role in delimiting and organising the island landscape to establish a community around a cult and also support a (maybe regional) political and cultural identity, as might have been the aim of the Ayia Irini votives[62] (Fourrier 2007: 121, 124; Papantoniou 2012: 96-97).

The political and cultural identity might also explain the position of the votives in the sanctuary and the type of characters represented. Houby-Nielsen (2016: 111-112) observes that the position of the statues and statuettes relates to an arrangement of the objects according to specific ideas: the chariots led by figures with Egyptian and Persian characteristics are in a semi-circle close to the altar; behind them, there are two large groups of small standing figurines; the larger sculptures are between and also behind the small figurines groups. The different measures and attributes may have

[61] Ulbrich could not attribute some of the sites with certainty due to the bad state of conservation of their sculptures (Papantoniou 2012: 97), while doubtfully interpreted others on the basis of the solely evidences. Ulbrich classified Ayia Irini as a peri-urban sanctuary within the territory of Lapithos, possibly after the CAI since previously it was under the territory of Soloi, together with two other close shrines called Ayia Irini-Paleokastro and which she classifies as urban and suburban (Ulbrich 2008: 370, 376-378), and an ancient citadel identified as the anchorage of Melabron (Quilici Gigli 1971; Quilici & Quilici Gigli 1975; Nicolaou 1976). Particularly, Ulbrich is cautious in a possible different attribution of the Ayia Irini sanctuary respect to the one commonly accepted of a male war/fertility deity. In fact, the scholar highlights the presence of a goddess on a Sphinx throne and an Astarte figurine but, since both perish in the multitude of big size and small worshippers of which at least 95% are male priests, warriors, riders and chariot groups, she admits that the identity and gender of the deity is difficult to determine (Ulbrich 2008: 242).

[62] This phenomenon could be especially meaningful for the Ayia Irini big statues, for which Fourrier assumes a more numerous presence respect, for example, to those exposed in an urban-sanctuary such as Soloi. In the Ayia Irini case, a more impressive display possibly substituted the lack of monumental structures and asserted in that way its cultural identity within the kingdom territory (Fourrier 2007: 124).

indicated their status, while facial characteristics recall various ethnic origins, such as Egyptian, Levantine and Cypriot (Beer 2009: 37).

As previously mentioned, the British Colonial Government permitted the division of the Ayia Irini findings between Sweden and Cyprus. More than half of the figurines were transferred to Sweden, while the remaining part is in the Cyprus Museum in Nicosia (Cyprus).[63]

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[63] The Addendum provides an update of the museums hosting the Ayia Irini finds, The Medelhavsmuseet represents the largest and most important collection of Cypriot antiquities in the world outside Cyprus.

2.4 Types, typologies, and problems

2.4.1 Einar Gjerstad's general classification

This research relies on the reference system created by Gjerstad to categorise the Ayia Irini finds (Gjerstad et al. 1935: 774-797). Constructed in 1935, the schema subtly influences interpretation with its use of terminology. Table 2.3. is my attempt to schematise Gjerstad's general classification of the Ayia Irini finds.[64]

Table 2.3.
Schematisation of Gjerstad's classification (Gjerstad et al. 1935: 774-797).

	Ayia Irini material	Classes
STYLES	Terracotta Sculptures	Styles I – VI
	Stone Sculptures	Styles I-IV
	Bronze Sculptures	not sub-divided
TYPES	Animal Statuettes	Types 1-10
	Minotaur Statuettes	Type 1-3
	Small Human Idols	Type 1-16
	Large Human Idols	Type 1-4
OTHER	Pottery	
	Material (iron, bronze, silver, terracotta, faience, glass, and stone)	
	Function (glyptics, coins)	

64 The primary information on the Cypriot clay figurines come from the SCE studies (Gjerstad et al. 1935: 642-824, pls. CLXXXVII-CCL; Gjerstad 1963). Later studies rely on the descriptions and typologies created by SCE and on samples (Törnqvist 1970; Karageorghis 1993; Karageorghis 1995; Ikosi 1991; Ikosi 1991-92, Fourrier 2007; Mühlenbock & Brorsson 2016). Different frameworks and criteria lead these studies, and they rely on typo-technological or stylistic approaches, thus resulting in different descriptions and interpretations. Ikosi (1991, 1991-92) has a technological approach based on the identification of clay types, suggested as a criterion for the identification of different coroplasts. Karageorghis' study of the small male terracotta figurines (1995) concerns a selection of the Cypriot material, among these some Ayia Irini statuettes. The study relies on typologies associated with criteria of size or technique, and sometimes with stylistic criteria. Fourrier (2007) proposes a re-interpretation of the Ayia Irini material based on stylistic similarities: statuettes present similar characteristics that could indicate provenance from different production centers. Törnqvist (1970) faces a more stylistic study that starts from the clothes and armours, while Mühlenbock & Brorsson (2016) have a scientific approach based on chemical analyses.

Gjerstad differentiated artistic from religious objects by explaining that the small and larger statuettes “are not of an artistic, but only a sacred nature; not produced with artistic intentions, but only for religious purposes to be used as votive offerings” (Gjerstad et al. 1935: 777). Based on statements like these and the classificatory schema itself, Vassos Karageorghis concluded that Gjerstad used “style” to categorise pieces he judged artistic and “type” to categorise material culture (Karageorghis 1995).[65] Beyond the Pottery, which deserved a separate class, Gjerstad created additional categories as a catch-all for those objects that defied definition as artistic or votive. For these, Gjerstad used as upper classes their material or their function.[66]

For my research, Gjerstad’s treatment of the Small Human Idols is especially significant. He initially completed a minute classification of the statuettes considering all the typological differences, including shape, technique, and type of representation. He performed a detailed subdivision to see if the typological differences responded to a chronological character concerning the stratigraphy. The study proved that most of the typological differences had no chronological significance. Therefore, he arranged the statuettes under sixteen leading types (Figure 2.8), describing the varieties of non-chronological character under each type.

Nevertheless, Gjerstad did view the statuettes as evolving. Gjerstad applied the terms “advanced” or “more advanced” to archaeological finds, implying an unbroken chain that starts from primitive and moves toward advanced.[67]

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[65] Törnkvist (Törnkvist 1970: 104) notices that the distinction relates also to the size of the objects.

[66] Fourrier (2007) underlines that Gjerstad’s subdivision relies on a mixture of typological, technological and iconographic criteria.

[67] Gjerstad’s aim was therefore to organise the mass of the Ayia Irini material to find a chronological meaning. Also his “styles” have a chronological sense, and the terminology used represents it: a sequence that goes from “proto-Cypriot” to “neo-Cypriot”. This succession of “Styles” relies on the Ayia Irini stratigraphic data that, according to various scholars, is questionable. On the base of these assumptions, such a stylistic chronological sequence, adapted to the statues, is difficult to apply to stone sculpture and for sure impossible to terracotta figurines (Fourrier 2007: 14-15).

SMALL HUMAN IDOLS

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Type 11	Type 12	Type 13	Type 14	Type 15	Type 16
Period 3	5											1				
Period 4		3	2	43	1352	15	81	5	1	1			3	3	18	
Period 5				1	43	9	12	1							1	
Period 6					41	58	4	3	1		2					
Period 4—6					1	1		2							1	
Period 7																1

Figure 2.8
The total number of Small Human Idols reported in the table by Gjerstad et al. (1935).

As Gjerstad admits, his first idea of classifying the Small Human Idols according to all noted typological differences (e.g., shape, technique, and representation) would have created more than fifty types. For this reason, he chose to organise the material in fewer, more populated groups. He divided them into sixteen main types but struggled to create clear categories, causing ambiguities since criteria overlap between types. For example, the arm positions of figurines in Types 5 and 6 are similar. According to Gjerstad, the Type 6 arms are “more detached” from the body, which he ascribes to an advancement in the production technique, without considering other possibilities, such as artisans’ diverging ambition and skill (Gjerstad et al. 1935: 787). Many of the varieties recur in several types, leading to overlaps, especially in Types 5 and 6, which constitute a majority of the Small Human Idols (Gjerstad et al. 1935:785-786; Karageorghis 1995:5).[68]

68 “*The items mentioned* […] *present characteristics of Gjerstad’s Type 6 (SCE II, 787)* […]. *The arms, however, are occasionally attached to the sides of the body, as for Type 5. It seems that there are not really any clear-cut characteristics for the two types*” (Karageorghis 1995: 5). Moreover, Karageorghis (1995: 1) underlines how other issues were detected in the attribution of the statuettes to a specific Type. For instance, for what concerns the group of the “single man human figures standing in a frontal position with arms stretched along the body”, whom Gjerstad attributed to the Types 4-6, in his supplementary catalogue (Gjerstad 1963: 27, fig. 40) it happens to find these artefacts also in other types (e.g., we find the figurine no. 2805 in Type 4-6, while in the 1963 catalogue in Type 3. That demonstrates that his classification lacks clear attributes that can help identify where the object belongs in the right way.

Adding more confusion, Gjerstad did not list inventory numbers along with the totals he gave for each Type/Period of the Small Human Idols, explaining that it was impractical to do so with a large number of objects. However, in the case of smaller and maybe more spectacular groups such as the Large Human Idols, Animal Statuettes and Minotaur Statuettes, the record includes inventory numbers. Without inventory numbers, it is impossible to re-assess the groupings that produced figure 2.8 and Gjerstad's stratigraphic attributions.

2.4.2 Einar Gjerstad's criteria for a typology of the Small Human Idols

Table 2.4 is my attempt to summarise Gjerstad's criteria for classifying the Small Human Idols. His work on the statuettes relies on a visual investigation of criteria such as iconography (arm position, dress, headgear), technique (hand-made, wheel-made, and moulded), clay (e.g., red/red-brown; light-brown), slip (e.g., red/red-brown slip; light/white slip), and decoration (black and red; black; red).

Types 1-11 include individual standing figures (1,687 items). Type 12 includes only one unique seated female figurine. Types 13-15 include the rare groups of dancers, riders, and chariots (26 items). Type 16 includes only one moulded Hellenistic Aphrodite head. Types 8-16 include statuettes whose characteristics differentiate them from the others in technique or iconography (e.g., modelled legs instead of a tubular body, heads with specific shapes, and representation of groups of small interacting figurines).

Types 1-7 are distinguished not so much by one main criterion but by a combination of many, in the sense that one single criterion may occur in several of these types, which means the classification becomes debatable to a much greater extent than in Types 8-16. For example, Types 1 and 2 include hand-made and wheel-made bodies; but Gjerstad describes Type 2 as "more advanced". Wheel-made bodies characterise both Type 3 and 4, but Type 4 differs in the splaying of the base, prominent upper part (corresponding to "torso" and above), and richer rendering of facial features. Types 5 and 6, both handmade, are remarkably similar except for the colour of their clay. Type 7 statuettes frequently carry instruments or offerings and have wheel-made bodies and moulded heads.

The identification of no-clear-cut criteria and their overlap between types highlight ambiguities in creating groups and classes through a merely qualitative method. That is more evident in some types (e.g., Type 5 and 6) than others (e.g. Type 7), but they all help contribute to testing the quantitative approach for the (semi)automatic classification of coroplastic material. For this reason, the sample for the present study includes figurines classified as belonging to Gjerstad's Types 5-7.

Table 2.4
Gjerstad's typology of the Small Human Idols (Gjerstad et al. 1935: 786-790).

Type	No. of items	Description
Type 1	5 items	Statuettes similar, but smaller, to the Large Human Idols Type 1. Trumpet-shaped hollow body, hand-made or wheel-made; gross head; rough face details: prominent nose, pellet eyes or eyeballs, and incised mouth (sometimes with pellet lips). Uplifted arms (Gjerstad et al. 1935: 786, CCXXIX).
Type 2	3 items	Statuettes similar to Type 1, "*but more advanced in type*". Disc-shaped head (Gjerstad et al. 1935: 786, CCXXIX).
Type 3	2 items	Statuettes with tubular, wide, wheel-made bodies. Small triangular head. Roughly shaped nose, globular eyeballs with eyebrows (face details painted). Arms bent, sometimes holding an animal. Straight and tall helmet. Body size similar to the larger statuette but with a small head. (Gjerstad et al. 1935: 786, CCXXIX).
Type 4	44 items	Statuettes similar, but smaller, to Type 2. Tubular, wheel-made body splayed at the base. Prominent breast and vertical arms. Square or trapezoid head with beard. Thin, pinched nose; prominent eyeballs; pellet ears. Straight spiked helmets or bands (Gjerstad et al. 1935: 786, CCXXIX).
Type 5	1437 items	Hand-made; red or red-brown clay with the same colour slip (sometimes, lighter clay with a lighter slip). Cylindrical and solid body splaying towards the base. Heart-shaped trunk, with arms and body from one piece. Oval, rectangular, trapezoid or wedge-shaped head. Pinched nose and pellet ears; different beard shapes (short, pointed, long, straight-cut, rounded). Pellets eyes and incised mouth. Vertical arms along the body with no accessories, but sometimes in different positions: advanced or upwards, one vertical and another on the breast, uplifted like for adoration. Represented as flute players or warriors (with a sword or a shield) and as worshippers with animals or votive gifts. Usually, with pointed caps or helmets of different shapes (short, long, straight, soft, with bent top), possibly realised in one piece with the head. Sometimes, the helmet realised separately from the head and with cheek-pieces, down or upturned. Few figurines with no hats and some with headbands. Dress not usually indicated plastically, but sometimes with clay or coloured details (sleeves, plain mantle or draped shawl). Simple and geometrical decorations (black and red). Traces of colour on eyes, beard, and hair. Few hollowed items (Gjerstad et al. 1935: 786-787, CCXXX, CCXXXI).
Type 6	83 items	Hand-made figurines with light brown clay and beige or white slip. Cylindrical and solid body's shape; base not usually splayed as in Type 5. Square or trapezoid head shape, thinner towards the upper part. Figurines made with snowman technique[69] (as Type 5); wig-shaped hair. Similar arms position as in Type 5. In Type 6, arms along the body but slightly oblique and detached from the body, producing a sort of triangle with the shoulders. Pointed helmets with straight, short sides and very few variations or bands (very common). Chiton not rendered but mantle or shawl usually straight and rounded. Face and dress details sometimes painted. According to Gjerstad, these statuettes demonstrate the advancement in the technique (Gjerstad et al. 1935: 787, CCXXXI, CCXXXII).
Type 7	97 items	Moulded heads; hollowed body splaying towards the base; vertical arms (or one bent over the chest, upraised arms or bent over the chest holding a tambourine or a small animal). Heads created separately from the body. Moulded faces and touched up with added details (beard, eyes, and ears). According to Gjerstad, 5 different moulds exist: - <u>Mould 1</u>: male ovoid face, soft, rather thick, wide lips, nose with upturned tip;

[69] The snowman technique consists of creating a solid cylindrical body splaying at the lower part while on the opposite the head has the shape of a high conical helmet.

		narrow, lancet-shaped eyes. - Mould 2: male face similar to Mould 1, but larger, and more triangular. - Mould 3: female face rather thick, small lips, curved nose, semi-lunar eyes, and wig-shaped hair.[70] - Mould 4 similar to Mould 3, but larger and more triangular, with broad forehead and narrow eyes. - Mould 5: Cretan-type female face, with hair falling in contiguous, transverse plaits on either side of the neck (only one item, A.I.2172). Face and body painted details as in Type 5 and 6 (Gjerstad et al. 1935: 788, CCXXXII).
Type 8	11 items	Statuettes moulded in one piece (sometimes parts added and changed). Four moulds identified: Mould 1: male figure with a flat body, isolinear feet out of the chiton; left arm vertical and right one folded in the fringed mantle; trapezoid head, long and rounded beard incised with face details (eyes, mouth, and nose). Mould 2: male figure with flat body and tunic; bare legs and isolinear feet; arms bent on the breast (no. 1416). Mould 3: male figure (previously female) with a flat body and tunic, right arm vertical and left one bent on the breast; isolinear feet, square head, tick nose and mouth; hair falling on the neck under a tall flat top helmet (no. 1060). Mould 4 naked female figure with isolinear feet and vertical arms ovoid head with details of the face (no. 1752). Another item (no. 2438), transformed into a male figure. Face and dress details painted (Gjerstad et al. 1935: 788, CCXXXIII).
Type 9	2 items	Statuettes with modelled separated legs and isolinear feet (nos. 90; 114+115). Trapezoid head, rough modelled face. Vertical arms. Dress indicated. Soft cap or without. Similar to larger statuettes and statues (Gjerstad et al. 1935: 788-789, CCXXXIII).
Type 10	1 item	Statuette (no. 1560) with tubular body and double face head with helmet (Gjerstad et al. 1935: 789, CCXXXIII).
Type 11	2 items	Human statuettes (nos. 809; 2170) with bull´s masks (Gjerstad et al. 1935: 789, CCXXXIII).
Type 12	1 items	Female statuette (no. 1563-2026) sitting on a throne with sphinxes (Gjerstad et al. 1935: 789, CCXXXIII).
Type 13	3 items	Ring dancers and musicians (nos. 123; 1169; 1693+2083) assimilated to Type 5 and attached to a base (Gjerstad et al. 1935: 789, CCXXXIII).
Type 14	3 items	Horse riders assimilated to Type 5 (nos. 921; 922; 1366). Horses with short and straight bodies with peg-shaped legs. (Gjerstad et al. 1935: 789, CCXXXIV).
Type 15	2 items	Horse chariots with drivers and warriors. Human figures with solid cylindrical bodies and heads similar to Type 5 or Type 7 (similar to Mould 1) (Gjerstad et al. 1935: 789, CCXXXIV, CCXXXV).
Type 16	1 item	Hellenistic Aphrodite head (Gjerstad et al. 1935: 790; no. 2176)

2.4.3 Einar Gjerstad's use of Reference-Figurines

Due to the substantial number of statuettes and variations, Gjerstad chose to categorise the Small Human Idols concerning what he described as "a restricted number of figurines," which I have chosen to call Reference-Figurines.[71] Rather than returning to describe the complex series of criteria

[70] Gjerstad mentions that the heads of Types 3 and 4 are "usually superficially transformed into male ones by adding a painted beard" (Gjerstad et al. 1935: 788).

[71] Gjerstad does not use this term. I employ it to indicate how he uses a restricted number of figurines.

that defined his main typology, Gjerstad satisfied himself with a formula such as “statuette similar to no. XX” instead of, for instance, a statuette belonging to Type 5. This means that he seldom accredits type-belonging to single statuettes. Instead, he relies upon Reference-Figurines to describe similarities. To these, he adds individual characteristics. He does not systematically attribute Reference-Figurines to all items or accredit types to all Reference-Figurines. Of the 103 statuettes sampled for the present study, only seven are explicitly attributed to types – one to Type 5, one to Type 6 and five to Type 7.

The sample used for the present study can be affiliated with seventeen “main” Reference-Figurines, of which five Reference-Figurines were digitally acquired.[72] “Main” is used here to mark the fact that Gjerstad, with predilection, proceeds to further comparisons, thus creating a chain of references which, sometimes, as in the case of Type 7, ends in one single reference-figurine: A.I. 52 (Figure 2.9). So, for example, if we consider A.I. 88, part of the sample for the present study, we learn that it is similar to A.I. 83. When we go to the entry of A.I. 83, we learn that it, in turn, is given as similar to A.I. 52, main reference figurine, and end of the chain of similarities for all items belonging to Type 7. Therefore, all the sampled items belong to Type 7. Although they may present obvious visible differences (e.g., different moulded heads, different base shapes), all Type 7 statuettes connect to one final reference-figurine, A.I. 52.

A comparison between figurines for which Gjerstad gives a common “intermediary” reference figurine is not more explicative. The scrutiny made of them for the present study clearly shows significant differences also at this early stage of the chain between, for instance, A.I. 88 and A.I. 877, both referenced to A.I. 83 as “intermediary” Reference-Figurine (Figure 2.9). Moreover, Gjerstad et al. (1935:788) suggest using five different supposed moulds to produce the Type 7 statuettes, but they provide no correspondence between these and the statuettes. Hence, there is no clear relation between specific statuettes and possible moulds.[73] An appropriate problem for digital quantitative analysis and a goal of this study is to define the number of moulds and the possible association between statuettes and moulds.

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[72] One of this, A.I. 52, possibly corresponds to A.I. 3893 (museums’ curators gave the new ID because of the lack of inventory number on the figurine).

[73] Ikosi, in her work on the Ayia Irini terracotta material, provides some information regarding the moulded heads technique of the figurines. Nevertheless, she does not provide further information about the association between moulds and statuettes (Ikosi 1991:272, 274, 305, fig. 31).

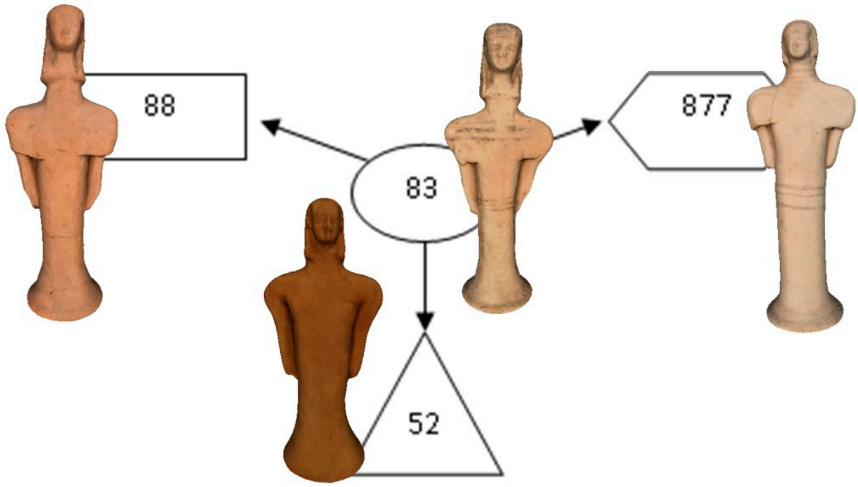

Figure 2.9
Example of visual comparison to detect similarities and use of same moulds between Type 7 statuettes assimilated to same intermediate Reference-Figurines. All the statuettes refer to one Reference Figurine (A.I. 52), but there are differences among the intermediate statuettes that can be significant for their interpretation. For example, A.I. 88 and A.I. 877 have A.I. 83 as an intermediate figurine. Although A.I. 88 and A.I. 83 have some similarities, there are differences with A.I. 877, plus they all differ from A.I. 52, the common reference figurine. In this case, even if both A.I. 88 and A.I. 877 have A.I. 83 as an intermediate Reference-Figurine, they do not present similar characteristics (e.g., different moulded head, different body) (Vassallo©).

Such concatenations are more complicated in Types 5 and 6, where Gjerstad used at least sixteen main Reference-Figurines. When Gjerstad does not explicitly attribute a figurine to a Type, we can follow his references back to a statuette for which he did attribute a Type; however, this system is laborious and time-consuming. For example, figure A.I. 130 (part of this research sample) does not present an attribution to a Type, nor is its Reference-Figurine A.I. 124. However, Gjerstad associated A.I. 124 with A.I. 1833, which he places in Type 5. It means that we can infer A.I. 130 as belonging to Type 5. That is tedious work and not always rewarding!

There are more figurines in the present sample (e.g., A.I. 217, A.I. 984, A.I. 760) that have Reference-Figurines but lack a Type designation (e.g., A.I. 73, A.I. 138, A.I. 221) and for which there are no more clues to Gjerstad's reasoning. As shown in Figure 2.10, some figurines are explicitly attributed to a Type (e.g., A.I. 816 directly attributed to Type 5; A.I. 60 directly attributed to Type 6), and others through the Reference-Figurine system to one or another Type (i.e., A.I. 1223, A.I. 195 and A.I. 981 to Type 5; A.I. 28, A.I. 895 and A.I. 37 to Type 6). Some statuettes are attributable to two Types (e.g., A.I. 233), while others are not given any Reference-Figurines or Type (e.g., A.I. 834, A.I. 125).

The reduced number of items in the present sample makes the direct individual figurines comparison easier. For instance, it is possible to easily spot resemblances which did not strike the eye of Gjerstad. However, the digital approach can be the final test or refinement of his concatenations.

The lack of explicit attribution of all the figurines to Types and the preference for a description of similarities through concatenated Reference-Figurines complicate the task of following and verifying Gjerstad's classification. However, his concatenated similarity approach demonstrates an outstanding ambition to order the statuettes found at the sanctuary. It can be that a continuation of this line of work could have led to the identification of specific characteristics also related to production patterns. An explicit attribution of the figurines' inventory numbers to the resultant groups of the SCE classificatory study would have been useful for a complete revision. I will make such an attempt for the sample studied in this research.

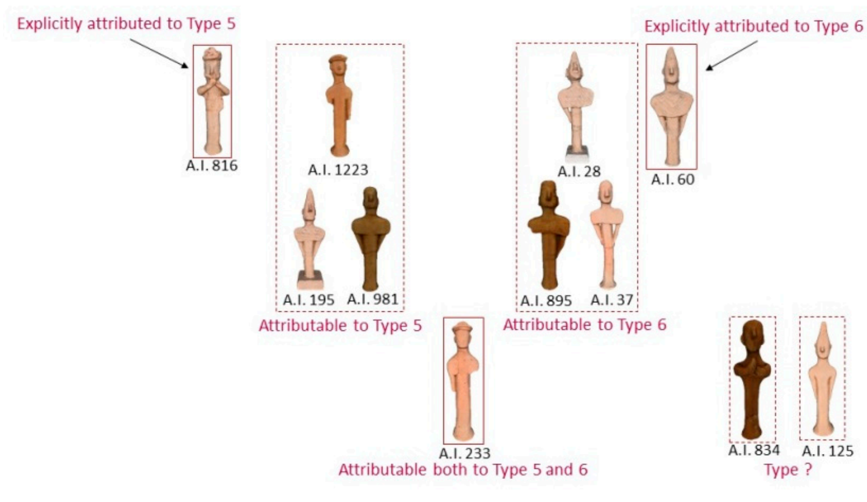

Figure 2.10
Example of Gjerstad's attribution of some statuettes to Type 5 and 6 (Vassallo©).

For Gjerstad, Types 5, 6 and 7 connect with the chronological periods he attributed to the sanctuary (Figure 2.8). The SCE classification sought to find connections between the figurines, their stratigraphy, and a chronology of the site; in this way, the chronology unduly influenced the categorisation of the figures. Gjerstad and his team did not explain some important details. First, they do not clarify the co-presence of 1,352 “less advanced” Type 5 figurines and 81 “elaborate” Type 7 statuettes in Period 4.[74] Second, the number of figures dramatically drops from Period 4 to 5. Third, Gjerstad describes Type 6 as a “more advanced” version of Type 5, but they are found in small numbers in Periods 4 and 5 and then increase in Period 6. This pattern hardly justifies Gjerstad’s idea of advancement in technique as an “engine” of development. Beyond the chronological deposition, we should consider other types of reasons, including origin and workshop. Any critical examination of Gjerstad’s diagram (Figure 2.8) highlights that his chronological sequence obscures an accurate analysis of the deposition of the statuettes. At the present stage of this work, we should not exclude other explanations. For instance, Houby-Nielsen's rejection of the stratigraphy is interesting, as she suggests a deposition order decided by other criteria than time, such as clusters of similar objects according to the worshippers' different social status or origin (translated into certain choices of figurines and places of display). If the stratigraphy is incorrect and all figurines belong to one large chronological frame, their differences may result from diverging skills and creativity.

2.4.4 Sample and catalogue

The digital analysis of the 3D geometries is necessary to verify the presence of fixed measures, ratios, and production process and extract production elements and see if any standardisation in the production itself exists.

The present study focuses on small-size representations of individual, standing figures: since this group has the largest number of artefacts, I needed to conduct a sample. There are diverse types of sampling: *random*, *casual,* and *non-random but thoughtful* (Gillis 1990: 3-5; Richardson & Gajeswski 2003). I used all three types of sampling for this research. The location and accessibility of the collections influenced my sampling choices. I sampled all the statuettes in cases where the museum collection is small. This was impossible at the Medelhavsmuseet and the Cyprus Museum. Other factors also influenced my sampling choices – for example, objects’ position in vitrines, on loan, or being conserved were unavailable for sampling, and I had to make substitutions. I began the sampling at Lund Historical Museum, where I selected 10 statuettes belonging to Gjerstad´s Types 5, 6 & 7 and the

[74] The terms “less advanced” and “elaborate” are a characterisation of the statuettes closer to Gjerstad’s mind.

height group from ca. 28 cm and below.[75] The random sample at the LUHM of figurines attributed to Types 5, 6 and 7 became decisive for my selection. Nevertheless, this was not the only fact that directed my later sampling toward the three types above. Like Karageorghis (1995: 5), I noticed that Gjerstad attributed the figurines to the two types, 5 and 6, with possible mistakes. Therefore, I wanted to take those figurines to run a digital analysis and to see if a quantitative, automatic classification coincides with the traditional one or not. Furthermore, I sampled Type 7 statuettes because their distinct characteristics make them a perfect case study for 3D analysis – each feature provides a set of data we can compare with other types.[76]

I established a height criterion for selecting Types 5 and 6 figurines to perform a uniform digital acquisition of shapes for digital comparison. For Type 7, I did not employ a height criterion; instead, I sampled most of the artefacts. I made further choices based on Museum catalogues, thus following non-random but thoughtful sampling rules. Adhering to the rules of casual sampling, I occasionally substituted a piece with a similar appearance for one that proved too difficult or impossible to access.

There are 103 figurines in my sample: 10 from LU, 42 from CM, 48 from MM and 3 from MK. While a larger sample might produce different and more detailed results, time constraints, accessibility and permissions prevented a larger sample size. Nevertheless, as Gillis underlines, the size of a sample does not relate to the reliability of results, especially in groups with the far-reaching similarities of the small Ayia Irini statuettes. According to Gillis, “it is not at all certain that this relationship is causal, i.e., that the amount of variables is directly related to sample size” (Gillis 1990: 5).

According to the SCE classification, 1,617 Small Human Idols comprise Types 5, 6 and 7 (see Figure 2.8). My sample of 103 items represents 6% of the Small Human Idols. More specifically, my sample includes 60 figurines belonging to Types 5 and 6 (representing 4% of the total) and 43 statuettes belonging to Type 7 (44% of the total). I did not choose the sample to mirror Gjerstad’s types. Type 7 makes up a larger bulk of the sample because they bear characteristics that are more suitable for this pilot study, namely applying computer algorithms to produce a digital analysis.

To clarify the sample and, through tedious effort, I retraced the concatenation from figurine to Reference-Figurine to relate it to Gjerstad’s

[75] LUHM houses other pieces from Ayia Irini: in total, there are 13 statuettes.

[76] Obtaining a set of 3D models of objects currently scattered among several museums and making it available for further studies may serve as an example for work in the future on similar cases of distributed assemblages.

typology. The sampled 103 statuettes result as representing a whole in which: SCE attributes 39 statuettes to Type 5 (1 attributed to the type directly, and 38 defined based on the Reference-Figurines); 11 figurines possibly belong to Type 5, according to the similarities, where the SCE gives no explicit reference; through the Reference-Figurines we end up attributing 3 statuettes both to Type 5 and to Type 6; Gjerstad et al. attributes 4 statuettes to Type 6 (1 directly and 3 through Reference-Figurines); it is not possible to assimilate 1 item to any other figurine, but its appearance might suggest an attribution to Type 6 (Figure 2.11).

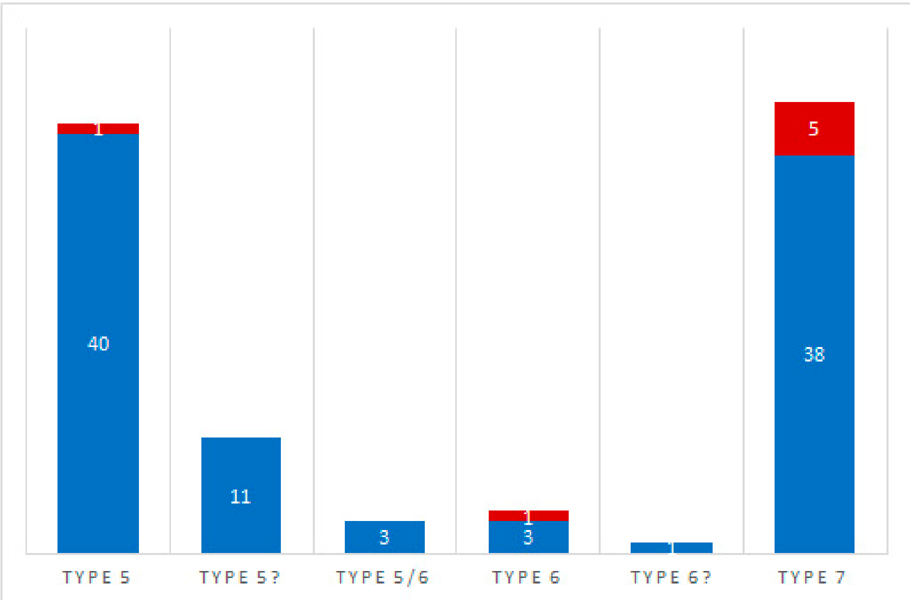

Figure 2.11
Attribution's attempt of the sampled 103 statuettes to SCE's Types, following the Reference-Figurines system. The graph highlights the uncertainty variable (e.g., the number of figurines we can attribute both to Type 5 and Type 6; the number of figurines we can attribute to Type 5 or Type 6). The red is the attribution through explicit association with Types; the blue corresponds to the association through Reference-Figurines (Vassallo©).

A close examination of the SCE classification system, including the Reference-Figurines, revealed the identification of additional sub-groups within the sampled Types. I believe that to examine the production behaviours of the Ayia Irini community and the use of these objects, we must search for more similarities and characteristics. This way, we may be able to attribute details to specific hands and finds to context position levels, thus helping us establish production patterns and a relative chronology.

I was able to cluster the 103 figurines (10 items from LU, 42 items from CM, 48 items from MM and 3 from MK) into 14 sub-groups based on similarities of artisans' "trademark" criteria, including body shapes, body creation, helmet shape, head shape, and shawl shape (Figure 2.12). In creating the sub-groups, I considered Gjerstad's Reference-Figurines. In some cases, for example, for Type 5, this helped me keep track of the similarities. In other cases, the Reference-Figurines lacked similar characteristics. As a result, further sub-groups appeared within the general type division carried out by the SCE. The catalogue created for this research includes the descriptions of the original SCE publication and those of the respective museums.[77] The aim is to create a unified version of the description and identify keywords for two related aims: the detection of the common terms for further help in clustering the statuettes into sub-groups and the identification of the statuettes parts' terms for the elaboration of a terminology/partonomy (Chapter 3). The partonomy is useful to the semantic analysis that, together with the geometrical and analytical one, allows successive comparison and interpretation (Chapters 4 and 5).

By working with a larger subset of elaborated statuettes, we increase the range of criteria we can apply to more generic statuettes. For this reason, we must identify fundamental characteristics, including shape, technique, and surface treatment. The shape of an object includes a description of its shape and measurements. The technique describes its material as well as the process of production. Finally, the surface treatment includes slip and surface decoration. This final category is the most complicated as we have few descriptions of these statuettes' decorative patterns and lack of pigments' remains. For this reason, thorough cataloguing of the artefacts combined with analytical investigations might lead to new groups, interpretations, and comparisons.

Working with this large group, I hope to identify common patterns and establish new subgroups of diverging significance.

The attached Catalogue presents all of the data from my sampling efforts.

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[77] Törnkvist, in her dissertation, corrects some incongruities identified between figurines' inventory number and the catalogue (1970: 5). She also underlines that a direct check of the artefacts was necessary, but the location in different museums and countries complicated the work. I had the same issue during the analysis of the sampled figurines. My unified catalogue aims to highlight and correct the mistakes or lacks found in the description of the SCE (Gjerstad et al. 1935) and of the hosting museums. Such issues definitely call for a future revision of the whole material.

Figure 2.12
Examples of figurines belonging to Gjerstad Type 5-6 (left) and Type 7 (right) (Vassallo©).

3.Research methodology

This chapter describes the methodology based on a 3D digital and analytical approach coupled with semantics and its development to meet the current research aims. In this vein, the chapter will review the state of the field. To that end, this chapter begins with a selection and explanation of methods, technologies, and instruments tailored to the problems presented in Chapters 1 and 2. More importantly, this chapter outlines the advantages and disadvantages of these methods compared to traditional ones.[78]

A part of the chapter will focus on describing the chosen methods, technologies, and the *iter* followed, highlighting the issues encountered and proposed solutions.

3.1. A 3D digital and analytical *chaîne opératoire* approach for the study and analysis of archaeological collections

Research methodology workflow

Developing a methodology involving different disciplines requires all the steps of the work and their relations to avoid any possible bottlenecks and find solutions in case of issues. Knowing the entire pipeline is fundamental to the success of the final result since every step of the procedure is connected and will affect the others (Vassallo et al. 2006: 422-423; Moitinho de Almeida 2013: 99).

This chapter focuses on the methodological pipeline developed for the current research (Figure 3.1). Specifically, the workflow starts with selecting the proper documentation methods (3D digital and analytical) and suitable

[78] The best solution is always the integration, both at the methodological and technological level. This chapter and Chapter 4 will further highlight the concept for what concerns the application of the research methodology to the case study.

artefacts. The workflow focuses on post-processing to obtain a 3D digital reproduction of the objects and phyisico-chemical data. Afterwards, the pipeline consists of extracting measurable information for performing geometric analyses and the analytical data for the artefacts' material characterisation. The procedure ends with the final interpretation by integrating the analyses' results, the combination with semantics aspects, and the corroboration with spatial data. The following section will describe in more detail all the steps developed for this research (Vassallo 2016; Vassallo 2017).

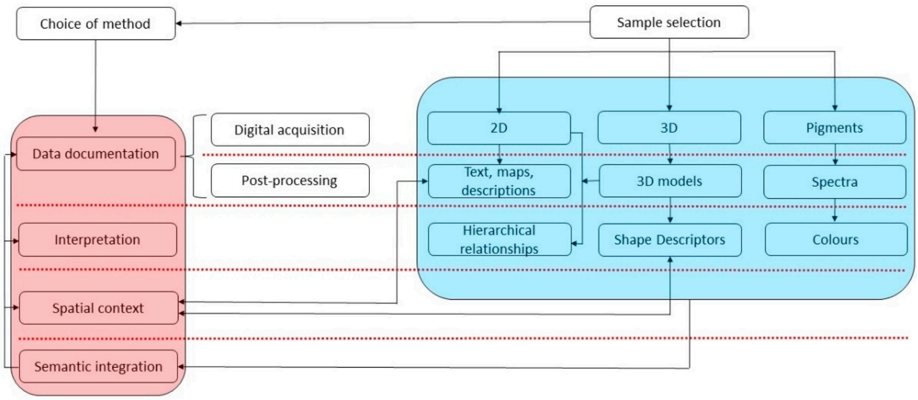

Figure 3.1
Schematic representation of the research methodology workflow (Vassallo©): it is critical to plan and organise steps and relationships (Vassallo©).

1. Sample selection

An essential part of the methodology's development is the selection of artefacts. The choice depends on the problems identified and the method employed. Identifying characteristics and attributes is preparatory to selecting the artefacts and their documentation, analysis and interpretation. The sample must be representative of the material under investigation, and it is crucial to choose a group of artefacts that is useful for extracting relevant information. Qualitative and quantitative criteria inform the sampling method.

2. Data documentation

Archaeological data carry heterogeneous and multi-disciplinary information that requires a combination of methods and techniques for documentation and description. It is, therefore, necessary to choose the proper method(s) depending on the object (e.g., a text, an image, a landscape, a site, a building, or an artefact) and the type of documentation needed (e.g., bi-dimensional, three-dimensional, chemical). Digital documentation surveys the artefacts and transforms them into measurable 3D digital objects to obtain geometric features that can be analysed. Analytical techniques physico-chemically document the artefacts to identify their material composition. In both cases, these kinds of documentation permit quantitative capturing of the geometry, the shape, the texture details, and the material composition of the artefacts, otherwise impossible to obtain with manual measurements or traditional documentation.

Moreover, 3D documentation limits the loss of information, instead usually present in traditional 2D documentation techniques due to lack of precision of the procedure itself and human error. This workflow step also focuses on establishing a 3D data acquisition pipeline (acquisition, post-processing, and data extraction), supported by standardised documentation and preservation of the parameters chosen, the passages run, and the final results obtained (cf. section 3.4.2). Data documentation applies both to the artefacts and their archaeological context. Complete documentation of historical and archaeological data (ancient sources, texts, descriptions, excavation maps, plans, and old photos) is, in fact, essential for the multi-disciplinary data integration for analysis and interpretation (Vassallo et al. 2006).

3. Data interpretation

After the documentation, the successive step consists of the data extraction for their analysis and interpretation. The historical and archaeological information about the artefacts and the context (e.g., maps, plans, sections, drawings, and old photos) creates a valuable dataset for the whole interpretation. We use 3D models to extract measurable information such as shape, size, and texture (shape descriptors) and perform geometric analyses and shape comparisons (shape analysis).

In archaeology, relating one artefact to another is integral to discovering information about its role, chronology, and production. Nevertheless, it is not easy to compare large numbers of artefacts. With 3D analysis, we can compare qualitative and quantitative data automatically (Hermon et al. 2010a). The geometrical representation of measurable 3D models and the extraction of quantitative features allow studying the objects' details, analysing and comparing them with millimetre precision. Analytical descriptors are extracted after the physico-chemical investigation of the artefacts' materials to characterise them and compare the results obtained. The semi-quantitative information regarding the materials' composition contributes to discovering the artefacts' production and provenance. Scientists also extract data from texts to produce standardised descriptions, semantic information, and formal and hierarchical relationships.

4. Multi-disciplinary data integration

The last step consists of integrating the multi-disciplinary data from the analyses for the final interpretation. It is necessary to integrate the bottom-up approach with the top-down one. Researchers must integrate the results of the 3D shape analysis with the critical study of the literature, archive sources, spatial and analytical data, and semantics. Cross-checking all the digital, geometrical, and analytical results with archaeological data relative to the material and the archaeological context (e.g., excavation diaries, original drawings, maps, and plans) represents the final step of the methodology. This workflow implies that all data (raw, processed, and interpreted) are opportunely standardised (see 3.4.2).

Tools for the current research

The proposed methodology relies on specific quantitative, semi-quantitative and semantic methods applied to the artefacts and their context to support traditional archaeological research (Figure 3.2). Specifically, the process relies on the following tools and methods:

1. The definition of a set of 3D descriptors to compare the geometry for the typo-technological characterisation of the artefacts, combined with physico-chemical descriptors.
2. A partonomy (a standardised vocabulary) to describe and formalise the parts of each artefact and their hierarchical relationships.
3. The development of a 3D Geographical Information System for the digital spatial re-contextualisation of the archaeological material investigated and newly analysed.
4. An ontological and semantic description for integrating all available data regarding the case study.

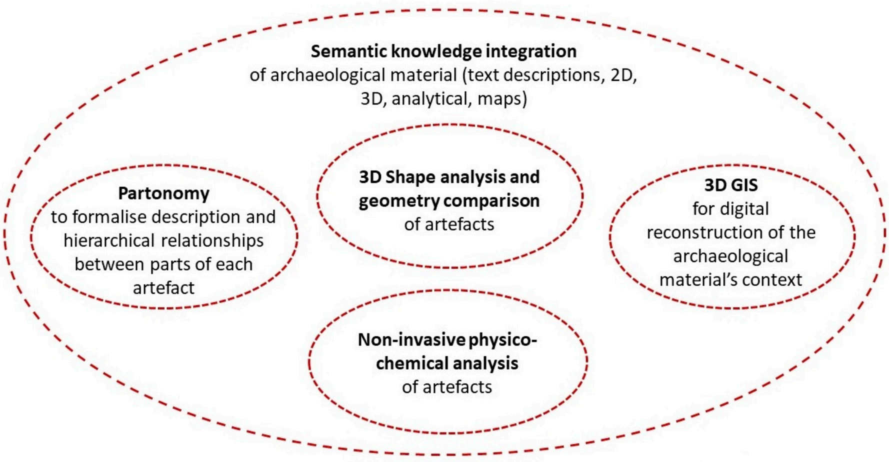

Figure 3.2
Schematic representation of the tools and methods used within the 3D digital and analytical *chaîne opératoire* approach to achieve the research aims of the current study (Vassallo©).

3D digital data documentation and analytical investigation

The next sub-paragraphs concern the whole digital data documentation carried out for the research. The review of the available technologies explains the reasons for the choices and procedures followed, the problems, and the proposed solutions. Regarding the 3D data documentation, the organisation of the sub-sections follows the structure already standardised by Daniela Peloso (Peloso 2005: 200). Indeed, as the scholar clearly states, the main steps of a job achievable with 3D data documentation technology, regardless of the procedures and solutions employed in the specific software used, are:

– 3D digital data acquisition;
– 3D digital data processing;
– Geometric information extraction.

The first step consists of capturing the point cloud constituted by the 3D coordinates (x, y, and z) of each point of an object's geometry; the second one consists of processing the unordered point clouds previously captured, generating a 3D digital surface model of the item and exporting it in specific formats. The last step consists of extracting meaningful information from the 3D digital data produced. The proposed methodology divides this step into two phases: in the first phase, we extract geometrical data; in the second, we extract those data whose analysis, procedures and results are treated in Chapter 4.

The last paragraph is dedicated to another type of digital documentation falling under the analytical methods and, in particular, to:

– Non–invasive material analysis.

In this section, a brief introduction and review of the techniques and methods available are propaedeutic to the descriptions of the chosen ones and the reasons for their selection. Information about the procedure followed anticipates the results of the analyses, treated in Chapter 4.

Choice of the method(s)

As described earlier, it is crucial to investigate the most suitable methods and technologies since several are available, with different technical characteristics and performance levels, determining advantages or disadvantages. The choice depends: on the objects (as visible in Figure 3.1, the choice of the methods is the connection between sample and documentation), what to document of those objects, the documentation's aim, and the use of the data afterwards. For this reason, the definition of relevant criteria for solving specific problems is fundamental. Otherwise, the objects remain passive entities, and their documentation does not provide further information. A series of variables can influence the techniques and software employed: the type of material, the geometrical and surface characteristics, the size and shape of the objects, personal choice, and tools' availability (Russo et al. 2011: 195). Therefore, it does not mean they are the 'best' methods and tools for this kind of research and its scopes, but they are the most suitable ones for the specific research needs at a date-time (Amico et al. 2012). Furthermore, the 'best' methods and techniques should capture and preserve the complete information about the artefacts, guaranteeing a framework for the long-term preservation of the outcomes (digital preservation) and the use of the raw data for current and future research (Vassallo et al. 2006; Vassallo 2017). Several methods, tools, techniques, and software are available today, both open-source and commercial.[79] Therefore, researchers must choose documentation methods based on the aims of the research and object type (Forte & Beltrami 2000; Vastenhoud et al. 2013).[80]

[79] Technologies and tools develop very fast, therefore their availability, constrained to their prohibitive costs until a few years ago, increased. For instance, many technologies, such as GPS, satellite imagery, and GIS software were born for military scopes. Nowadays, scholars use these technologies in Cultural Heritage and Archaeology daily (Forte 2002).

[80] *What are the aims of the research? What are the objects to be documented? What kinds of methods and technologies would be better and able to accomplish our goals? What are the reasons for applying such methods and technologies?*

Such a choice demands a broader range of research questions.[81] This preparatory work led to the choice of 3D digital and analytical documentation methods and specific technologies and tools within these two groups (see 3.2.1, p. 87 *et seq*. and 3.3, p. 126 *et seq*.).

3.2. 3D documentation

The first two passages of the research methodology, the Ayia Irini material selection and the collection of its historical and archaeological data, have been treated in Chapter 2. Information on the material and its context are analysed, the issues identified, and the artefacts for applying the research methodology are selected. The subsequent two steps of the methodology fall under the data documentation phase.[82]

State of the art on the use of 3D digital documentation and technologies in CH

For almost two decades, the use of 3D in archaeology and CH has been well known, together with the advantages brought by its application for various aims: documentation, dissemination, visualisation, archiving and preservation, conservation and restoration, virtual reconstructions, virtual reality, creation of digital replicas and 3D printings, only to name a few

[81] *What are the dimensions of the objects? Is it important to reproduce their exact dimensions and geometry? Are the textures and colours of the objects important to be documented? What will be the use of the data?*

[82] A related issue concerns the way measures are taken. In most cases, even when measures are reported, they are limited to global dimensions (e.g., height, width), are approximate (e.g., a curved surface measured by the ruler) and are often not distinctively defined or subject to inaccuracies. For instance, measuring the length of a statuette's arm involves choosing a distance metric (e.g., Euclidean versus geodesic measure) and the extremal points. Such a choice determines several questions, such as where exactly the arm begins and ends or if the measure of an archaeologist corresponds to the same measure of another archaeologist. It is clear that, first of all, it is not possible to define a measure in a linear system for a three-dimensional object; secondly, measurements taken by different people may be completely dissimilar. Moreover, the exact procedure followed is arduous to specify in a text commonly produced in archaeology. On the other hand, the quantitative approach carried out with digital tools is based on more formal metrics able to produce replicable results and assist the qualitative one in different ways. Firstly, a 3D model as a digital copy of the artefact allows pinpointing precise landmarks (e.g., measurement extrema, feature lines, areas of interest) and defining them uniquely. Secondly, a variety of shape analysis tools can be applied to obtain quantitative descriptors, directly in the digital domain and with no risk of damage for the real artefact, allowing for feature identification, (semi)automatic comparison of models (or parts of them) and classification.

(Reilly 1989, Reilly 1991, Rahtz & Reilly 1992, Beraldin et al. 2004, Guidi et al. 2005, Frischer & Dakouri-Hild 2008, Scopigno et al. 2003, Vico 2013, Apollonio et al. 2018, Hermon et al. 2005, Forte 2007, Forte & Pietroni 2009, Vico & Vassallo 2013, Alemanno et al. 2014, Maxwell et al. 2015, Amico et al. 2018).[83] During these years, 3D survey and 3D modelling techniques have proven to be valid support and an active contribution to archaeological interpretation. It is now more than ten years since Guidi et al. (2010) emphasised how digital data acquisition and 3D modelling had led to a growth in archaeological research and how the demand for using these techniques at different levels increased exponentially. The same authors, however, warned that technologies should fit into a well-coded cognitive process where researchers pay particular attention to the integration between traditional archaeology and technical methods (Russo et al. 2011: 169). Indeed, the support of technologies can help enhance the traditional archaeological approach, better managing data and contributing to interpretation and knowledge (Volpe 2008).

On the other hand, Huggett et al. (2018: 42) recently underlined how, although digital technologies now permeate every phase and aspect of the archaeological practice, their adoption and use have not always been uniform throughout all phases. While this diversity has led to greater openness and multivocality within the discipline, conversely, it has created a sort of unsustainability, perhaps due to not particularly rigorous standards.

Only well-documented (in terms of procedure standardisation and transparency) artefacts can be interpreted and reinterpreted in the light of changes in theories, methodologies (Renfrew & Bahn 2006) and even technologies.

This thesis employs tools and software that address specific research questions related to the artefacts in question (Vassallo et al. 2006; Vassallo & Palombini 2008). The complexity of digital documentation (due to the artefacts and other external factors) requires the instruments to employ a very high performance, which, unfortunately, for various technical limits, cannot be guaranteed by a single instrument. For this reason, integrating different 3D acquisition systems helps increase object information, obtain high precision and accurate results, and optimise the documentation process (Russo et al. 2011).

[83] For a more extensive overview, see also the proceedings of CAA - 'Computer Applications & Quantitative Methods in Archaeology', VAST - 'Symposium on Virtual Reality, Archaeology and Cultural Heritage' and EUROGRAPHICS Workshop on Graphics and Cultural Heritage.

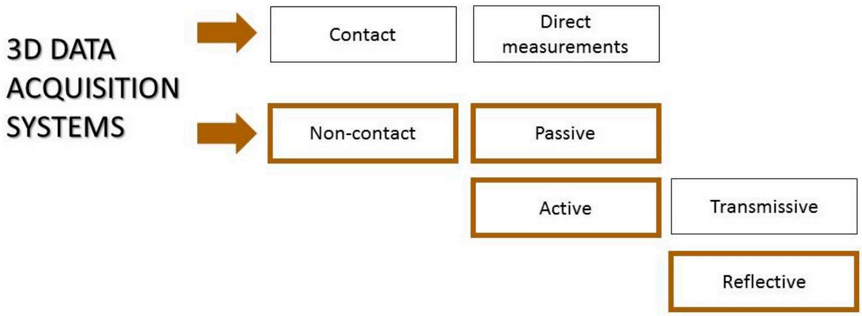

Figure 3.3
3D Data acquisition systems (adapted image from Moitinho de Almeida 2013: 101).

3.2.1. Digital Data Acquisition

3D digital data acquisition systems

The 3D digital data acquisition consists of digitally acquiring the 3D coordinates of an object's external surface (**point cloud**).

Different 3D data acquisition systems exist (Figure 3.3) in two categories, **contact** and **non-contact** modalities. The second group, non-destructive, allows acquiring 3D quantitative data of the object without any contact. Two subsets compose this group: **active** and **passive**. In turn, the **active**[84] techniques are composed of 2 subsystems: **transmissive** and **reflective** systems. Within the group, the most used technique in CH to acquire the geometry of an object is the one based on light radiations, through which the active sensors measure the distance between the instrument and the points of the object to survey.[85] This distance is then registered and transformed into coordinates (x, y, and z), digitally acquiring complex geometries very fast and accurately (Bernardini & Rushmeier 2002; Blais 2004; Guidi et al. 2010, Russo et al. 2011: 170).

These tools are based on the use of the laser. A laser is electromagnetic radiation. Therefore, a laser scanner is an electro-optical device; it can automatically measure the spatial coordinates of a point in space, thanks to the dual activity of a light emitter and receiver. There are different types of

[84] These 3D digital data acquisition techniques are mainly based on **range data**.

[85] Depending on the instrument, we can also have different quality colour information, registered by the sensor itself or by a digital camera integrated to it.

laser scanners, depending on the light emission and projection type (Laurini 2018:49-54): triangulation-based scanners with laser stripes, triangulation-based scanners with structured light, Time-Of-Flight scanners (TOF) and phase-shift scanners. According to the dimensions of the object (and the distance between sensor and object), it also changes the kind of sensor to be used: for example, sensors based on the triangulation measurement can be used for medium or small objects; while Time-of-Flight (TOF) sensors and phase-shift scanners can be chosen for bigger objects (e.g., buildings, landscapes) (Russo et al. 2011: 172).

Triangulation range finders (divided into laser striping and structured lighting[86]) work on a limited range of some meters and therefore have higher accuracy. Usually, the measurement uncertainty of the triangulation-based laser scanners is around 0.1 mm (Georgopoulos et al. 2010) (Figure 3.4).

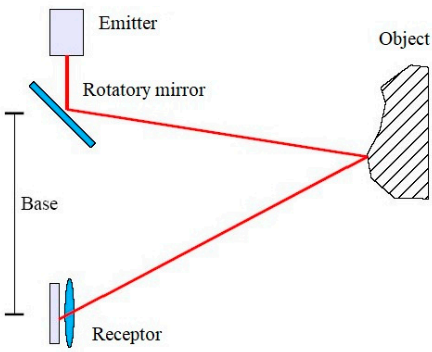

Figure 3.4
Researchers usually employ triangulation-based laser scanners for small and medium objects. These tools work on topographic principles and have a base with a rotatory mirror, an emitter and a receptor. The emitter sends the laser to the mirror that reflects on the object; the receptor registers the reflected radiation, and through trigonometric calculation of emitting and receiving angles, it is possible to measure the distance from each point of the object hit by the laser (adapted image from Laser scanner. In Wikipedia.htttps://it.wikipedia.org/wiki/Laser_Scanner).

The **passive**[87] techniques group includes all the image-based instruments: optical devices acquire the object through 2D images opportunely processed

[86] Structured light scanners work following the same principle of the laser striping, but instead of using a single laser, they project light beams with different patterns. These kinds of scanners reach a higher precision and accuracy respect to the previous ones. For a more detailed description of the different typologies of emission and projection of the light (laser lights and projected light pattern) see Russo et al. 2011:173.

[87] These 3D digital data acquisition techniques are mainly based on **image data**.

to extract measures. **Photogrammetry** is the most used technique in CH: starting from the identification of the same points in different images acquired by terrestrial, aerial or satellite sensors, it can obtain quantitative information regarding the dimension, geometry, texture and position of the surveyed object (Mikhail et al. 2001, Remondino & El-Hakim 2006; Russo et al. 2011).[88] There are different photogrammetric techniques available, and they require different levels of expertise: the ortho-rectification, according to which it is possible to identify the orthogonal projections of an image; the stereo-photogrammetry, applicable to images' couples and based on the physics principle of the stereoscopy and collinearity[89]; and the bundle-block adjustment, based on multiple images. In recent years, photogrammetry has received a boost thanks to the enhancement of the method and the integration with Computer Vision techniques, introducing and widely distributing the photo-modelling technique. Thanks to the development of specific algorithms and software, the images can be processed to find the object's spatial coordinates and produce a 3D graphic restitution.[90]

There are often combinations of active and passive techniques (El-Hakim et al. 2008) since both present limitations due to different variables, e.g., time and budget, tools availability, level of detail needed, and research aims (Manferdini et al. 2008). The integration provides better results both for the data acquisition and the modelling process since it helps to bridge the natural gap of each technique and produce higher resolution models (Russo et al. 2011: 195; Guidi et al. 2003; El-Hakim et al. 2004; Guarnieri et al. 2006;

[88] The image-based methods need a specific mathematical formulation (projective or prospective geometry) to transform the data extracted from the images into 3D metric coordinates (Remondino & El-Hakim 2006). The images bear all the information that is necessary to reproduce both the geometry and the texture of the artefacts photographed, making possible the generation of 3D models that have an optimal informative content (Russo et al. 2011: 172).

[89] Through the mathematical model of collinearity and the use of at least two images, it is possible to obtain metric information relating to the objects photographed. As it happens in human vision (right eye vision + left eye vision = 2 images taken from different points of view), photogrammetry, documenting the different positions - parallax - of the object in the images, allows to obtain the same stereoscopic view and to extract three-dimensional information from the overlapping areas identified in the images (Russo et al. 2011). It is essential to acquire the scene trying to cover the entire area of the object, avoiding invisible areas and having a good overlapping among the different images. In fact, it is possible to reconstruct the three-dimensions of a point in the scene only if that point is present and measurable in at least two images taken from different positions (Russo et al. 2011: 183).

[90] All the 3D data produced by range-based and image-based technique can be integrated with other metric information produced by direct measurements. This procedure allows us to scale the 3D models (Russo et al. 2011: 172).

Guidi et al. 2009, Georgiadis et al. 2009). Moreover, every archaeological object has different characteristics (material, size and shape) that prevent data acquisition techniques for all the scopes. Furthermore, every 3D digital data acquisition technique produces data with different levels of accuracy and resolution that cannot be good for all situations and objects.

Measurements' uncertainty: accuracy and precision

3D digital data acquisition technologies increased the accuracy of the objects' documentation, obtaining metric data with a maximum error in a range of millimetres and resulting in digital outcomes being less interpretative and subjective with respect to traditional data documentation. Nevertheless, different variables and factors affect all measurements, even the 3D digital ones. Moreover, every step of the documentation pipeline (digitisation and post-process) can bring errors in the final results.[91] There is sound research literature about this topic that analyses all the variables that could produce measurements errors: the instrument (e.g., accuracy, calibration, resolution), the operator (e.g., confidence, experience, skills), the environment (e.g., spatial and temporal coverage, vibration, temperature), the object material and surface effects (e.g., size, shape, texture) (Beraldin 2004; Georgopoulos et al. 2010; Boehler et al. 2003, De Felice et al. 2008).[92], In particular, Beraldin et al. (2007) discuss the main parameters connected to 3D dimensional measurements: geometrical resolution, accuracy and precision. The (maximum) resolution is the highest ability to acquire the details of a surface, which in turn is dependent on the optical, mechanical and electronic characteristics of the instrument (Guidi et al. 2010). Every time we measure something, e.g., a distance, we have a value that is never the exact representation of the truth. The variance of a measure consists of two parts: a systematic and a random one. The first one (accuracy) depends on the performance of the instrument; the second (precision) is due to unexpected variances during the measurement (Russo et al. 2011: 178; JCGM 2008;

[91] For instance, the method of producing a model from multiple 3D acquisitions involves the propagation of errors (Beraldin 2004). This procedure can, in turn, propagate the errors, causing uncertainty in the alignment of 3D images and, therefore, on the post-processing pipeline and the final model.

[92] It is essential to also consider the subjectivity of digital acquisition. The concept is also treated in photography. As stated by Bohrer "*the photograph does not just passively document, but actively argues for an interpretive position*" (Bohrer 2005:182). The same can be applied to 3D digital acquisition.

JCGM 2012; Li 2011). For this reason, it is crucial to consider measurement errors during 3D data acquisition.[93]

3D data acquisition plan for the choice of techniques and instruments

To better manage the uncertainty measures' information, it is advisable to know the instruments, choose and test them, and plan in detail the 3D procedure to avoid unreliable outcomes.

The testing/planning phase is undoubtedly the most delicate part of the 3D acquisition process. Correct results depend on initial choices. A critical aspect consists of choosing the instrument, its settings and parameters to control resolution, accuracy and precision. In turn, such characteristics depend on the evaluation of the object's features (e.g., size, geometry, and material) and the specific research requirements, including the budget, the time available, the operator experience and the environmental aspects (e.g., fieldwork spaces) (Russo et al. 2011: 170; Amico et al. 2012: 14). Beyond optimising the acquisition process (e.g., time/efficiency) and foreseeing possible bottlenecks (Beraldin et al. 1998), it also helps to evaluate how to operate to document the objects' geometry in the best possible way.

Given this preamble, I will focus on the activities carried out for the current research: the choice of the techniques and instruments, the tests performed, the capabilities and limitations of the approach used, and finally, the results achieved. Since integrating more systems improves accuracy, precision and quality and minimises uncertainties (Beraldin 2004), I combined two 3D data acquisition techniques to document the artefact's geometry and colour texture: triangulation-based laser scanner and image-based 3D modelling.[94] The last part of the chapter focuses on the data acquisition campaign at the different Ayia Irini conservation places and the post-processing to create the 3D models.

[93] For this reason, it is important to make available the raw data and to trace and make transparent all the steps of the digital acquisition workflow, also informing about any issues that occurred (see data and information transparency in paragraph 3.3/3.4).

[94] Some studies have been carried out on the comparison in the use of triangulation-based laser scanners, e.g. NextEngine, and image-based 3D modelling, e.g. Photoscan (Rodríguez-Navarro 2012; Remondino et al. 2014; Guidi et al. 2015).

Table 3.1
Triangulation-based laser scanner used for 3D documentation (Next Engine) and its technical characteristics.

Technical characteristics				
Compact aluminium box of 22×28×9cm size 	Twin arrays of four solid-state lasers (red, 650nm)	Twin 5.0 Megapixel CMOS Image Sensors	Acquisition speed is 50.000 processed points/sec	2/3 minutes per scan of each facet

Triangulation-based laser scanning for the current research

Due to the size of the sample, the material, the shape, and surface characteristics of the artefacts, the 3D data acquisition of the Ayia Irini small statuettes' geometry was performed with a triangulation-based laser scanner technique, specifically with a multi-stripe laser triangulation (MLT) system. I chose a NextEngine 3D Desktop laser scanner based on its affordability and strong reviews of its technical properties (Guidi et al. 2007).[95] Moreover, both Lund University and the Cyprus Institute own versions of this laser scanner.[96]

NextEngine projects multiple laser stripes that an internal CCD camera records to register the object points' position: it is a device composed of a compact aluminium box of 22×28×9cm size, provided with twin arrays of four solid-state lasers (red, 650nm) and twin 3.0 Megapixel CMOS image sensors. The acquisition speed is 50.000 processed points/sec throughout, and it typically takes 2/3 minutes per scan of each facet (Table 3.1). According to the object dimension and the digital acquisition required, we position the laser scanner on a stable surface and the artefact on the rotating base connected to the laser scanner at fixed distances. For 3D data acquisition of small objects, a good practice is to place them in a distance of 16.5 cm from the front side of the scanner (circa ±10-15 cm - Macro Mode distance), with

[95] See Guidi et al. 2007 for an evaluation of the performances of the low-cost NextEngine laser scanner compared to other triangulation-based range sensors; Akca et al. 2007 for a review of a coded structured light system for cultural heritage material; Georgopoulos et al. 2010 for an assessment of structured light scanner performances.

[96] Due to its affordable price and its good performance in terms of precision and accuracy, museums, Cultural Heritage institutions, and universities choose the tool for research and educational aims.

accuracy from the manufacturer of ±0.127 mm and with a maximum of ~16 points/mm; in case of bigger objects, the suggestion is to place them in a distance of 43.2 cm (circa ±37-42 cm - Wide Mode distance) with an accuracy of ±0.381 mm, with a maximum of ~6 points per mm. The scanner resolution is 200DPI in Macro Mode and 75DPI in Wide Mode.[97] Texture density on the target surface is 400DPI in Macro Mode and 150DPI in Wide Mode. In the case of Macro distance, the scanner field size is 12.95 cm x 9.65 cm, whereas, in the case of Wide distance, the scanner field size is 34.29 cm x 25.65 cm. Despite the limitation of the scanner field size, there is no size limitation for object acquisition; objects larger than the scanner field can be composite-captured (Amico et al. 2012; Athanasiou et al. 2013).

IB3DM -Image-based 3D modelling (photogrammetric digital data acquisition) for the current research

Other methods, based on the user-assisted detection and identification of some features and shapes in a set of different pictures of an object, can build an approximation of the object itself. This 3D imaging solution relies on the principles of photogrammetry. In the last years, the technique improved considerably, leading to a simplification and automation of the process in the production of 3D models and becoming one of the most widely used techniques in archaeology. The introduction of automated procedures for photogrammetry, such as the creation of the web-based software Arc3D (Vergauwen & Van Gool 2006), allowed a wider use in the archaeological field (see case studies application in Hermon et al. 2010a; Hermon et al. 2010b). The diffusion of image-based 3D modelling techniques from free, low cost and open-source software and automatic procedures using the Computer Vision approach started a revolution in documentation and 3D modelling. Researchers started to use other software widely, such as the Autodesk 123D Catch (Lo Brutto & Meli 2012; Kersten & Lindstaedt 2012, Santagati et al. 2013) and Agisoft Photoscan –now Metashape[98], probably the most used low-cost software in the last years (Verhoeven 2011; Doneus et al. 2011; Verhoeven et al. 2012; Lo Brutto & Meli 2012; De Reu et al. 2013; De Reu et al. 2014, Dell'Unto 2014, Dellepiane et al. 2013, Callieri et al. 2011; Guidi, Gonizzi Barsanti and Micoli 2014; Guidi et al. 2015).

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[97] The digital data acquisition produced data, with an average resolution of 0.02 and derived from an average of 20 range scans and a total of points of circa 2M for each statuette. Those points have been post-processed to obtain complete point clouds, readable and manageable, for each statuette.

[98] Recently, Agisoft Photoscan changed its name to Agisoft Metashape.

I also documented the Ayia Irini figurines through image-based 3D modelling techniques. This documentation guarantees a high-definition quality texture (RGB point cloud) and preserves the objects' visual characteristics: colours, material appearances, and microelements (Vassallo 2016). For this research, I selected the software Agisoft Photoscan-Metashape[99]. Its advantage is that it performs semi-automatically photogrammetric processing of digital images acquired with metric and non-metric cameras, and it also generates scaled and geo-referenced texturised 3D models (Dell'Unto 2014). The software does not set any requirements concerning the image resolution; however, it is reasonable to remember that the input data's resolution influences the quality of the processing results.[100] Following an automated pipeline, the software identifies the features, then calculates the camera positions and consequently generates point clouds. Finally, the texture is created by the photo-realistic texturing of the 3D model. The accuracy and the consequent analysis results of the 3D models depend on how they were obtained (e.g., the resolution of their acquisition and the quality of their post-processing).

3D data acquisition: tests, assessments and survey campaign

After selecting the 3D data acquisition systems and the instruments, it is appropriate to plan the survey campaign, given the performance of a series of tests.

For instance, due to the variables in the use of active sensors, literature reports various trials to achieve the best practice for data acquisition -and data post-processing- of archaeological artefacts (Abernathy 2007; Guidi et al. 2007; Kaneda 2009; Arnold 2009; Amico et al. 2012; Athanasiou et al. 2013; Morris et al. 2018).[101] For this thesis, I followed the cited guidelines and recommendations. Moreover, I performed further tests based on the

[99] http://www.agisoft.ru/

[100] That is why it is better to employ a camera with at least 5Mpx resolution but opt for a 12Mpx resolution photography if we want to produce professional-quality orthophoto maps. Some researchers obtained good results, by using smartphones cameras (8 Mpx) and tablets for image-based 3D modelling in public inclusion projects in museums (Bonacini et al. 2015). In many cases, these techniques gave impetus to the documentation of cultural assets at risk. A famous example is the photogrammetric reconstruction of the Buddhas of Bamiyan in Afghanistan (Grün et al. 2004) and of the Palmyra Arch of Triumph in Syria (Wahbeh 2018).

[101] Some authors made efforts in an attempt to define scanning protocols to obtain comparable accuracy from different sources (Moitinho de Almeida & Barceló 2012) and to produce calibration objects for the same purpose (Hess & Robson 2012).

material and the workspaces; I also reported all issues that emerged during data acquisition and post-processing to provide a transparent process and possible recommendations for other users.

Instrument calibration and parameters setting are essential in the 3D data acquisition procedure. For what concerns data acquisition of 3D active sensors, production companies usually do the calibration (Russo et al. 2011: 173). The operator usually sets the parameters. Amico et al. (2012) underline that the parameters influence the instrument's limitations. These elements are strictly connected with the methodology and could interfere with the accuracy of the final results. For this reason, I decided to record all the steps followed and the parameters set to review the entire procedure eventually or to allow re-use of the data in the future.

The setting of the parameters is related to the sensors used, the distance with the object, its shape, geometry and material, as well as the digital acquisition workspace.

At the beginning of any data acquisition, it is fundamental to accurately plan and choose the position of the sensor (be it active or passive) to perform correct and complete documentation of the object's geometry. Literature on triangulation-based laser scanning suggests overlapping 30-40% of the scans to cover the surface of an object (Russo et al. 2011: 177-178). Concerning the size of the investigated small figurines (maximum 20-30 cm), this operation is not particularly complex in terms of scans overlapping, but other characteristics, such as the non-linear objects' shape, complicate the whole procedure. For instance, in the present case study, it has been essential to 3D document the objects have areas of overlapping (and recognisable points for the alignment of the meshes during the post-processing phase) and cover their geometry as much as possible, using different and multiple viewing angles and scanner's positions. Nevertheless, often the non-visibility of some artefacts' areas causes a loss of some parts of the geometry, resulting in possible small holes in the mesh. According to some authors, it is better to leave the holes, not modify the geometry of the items and create a fake (Moitinho de Almeida & Barcelò 2013). This research follows that approach, declaring the presence of such gaps since, if they do not affect the quality and the integrity of the geometry, it is not a problem for the final result.

During digital data acquisition, beyond the issues related to the object dimensions and its geometry, it is important to consider other important factors for accuracy and resolution, such as the surface object characteristics (e.g., opacity, reflectance, light absorbency of the materials). For instance, different materials react differently to the laser: a shiny bronze surface, a glazed ceramic or glass objects are high reflectance materials, and therefore the laser could not digitally acquire their 3D shape and texture. Similarly, the laser cannot well acquire a black texture, while a more neutral surface (e.g., clay), thanks to its low reflectance, can absorb the laser and give good results (Moitinho de Almeida 2013: 103; Amico et al. 2012). In the present case study, although the terracotta of the Ayia Irini small statuettes did not create any issues during the digital data acquisition, the fine homogeneity of their clay caused some difficulties in the post-processing phase in recognising common points.

Finally, also the environment and the workspace play an important role. For instance, space, lightening, natural and human conditions can enhance or prevent good results during the 3D digital data acquisition (e.g., extreme temperatures can affect the results of digital acquisition and the instruments' performances; the presence of people could affect a laser performance both visually and in terms of vibrations).[102]

In some cases, museums have controlled environments (e.g., photography rooms) that can be used for digital data acquisition. Nevertheless, it is not always possible to use them, and as in the current case, I had to perform the survey campaigns in different spaces with consequent small issues during the documentation process.[103]

[102] An example of what the workspace conditions mean and how they can affect the performances of the instruments is presented by Bathow et al. (2008) and Abate et al. (2013).

[103] This phase of the work also comprises the evaluation of the places where the digital acquisition will happen and of the facilities available (e.g., presence of power supply for the instruments, eventual need of batteries and generators, need for tents for isolating the objects from direct lights) and consequently the preparation of all the necessary equipment (hardware -instruments and laptops- and software) and their transportation. For instance, apart from the digital data acquisition test carried out at Lund University premises, all the survey campaigns needed further organisation concerning the logistics: transportation of the instruments, lights, light-tent, power supplies, and power extensions. The only author of this research performed all the digital data acquisitions. Such a situation, especially for the fieldwork carried out in different cities, involved a significant effort in logistics and transportation.

Figure 3.5
3D data acquisition tests were performed in a controlled environment at Lund University with the NextEngine laser scanner. The documentation started with a first 360° scan and two further 180° scans (bracket scan) of the upper and bottom part of the statuette. These two further scans aimed to cover the parts hidden by the tool's grip and base, as well as all the hidden parts of the statuettes (e.g., the area under the nose and the beard) (Vassallo©).

Tests for triangulation-based laser scanner documentation

I performed several tests with a laser scanner and photogrammetry technique on some Ayia Irini statuettes to acquire geometric and colour data. The procedure aimed to understand if specific technical choices determine good or bad results and consequently to choose the best ones to obtain high-quality results. For the test, I selected objects with more complicated shapes in terms of geometry (A.I. 1916 and A.I.1507) to identify the best strategy for their 3D data acquisition.[104]

I also tested different digital acquisition parameters. Concerning the laser scanner acquisition, I placed the objects on the rotating table of the NextEngine. I set various preferences through its proprietary software (ScanStudio): data acquisition with or without texture, number of points per inch (from a minimum of 500 points/inch to a maximum of 4.4 K points/inch, depending on the employment of the standard software or the HD Pro version) acquisition time and results' accuracy. During the tests (Figure 3.5), I performed a first 360° degrees acquisition, in Wide Mode, of the statuette standing, and then I completed a second 360° degrees turn of the statuette laying to cover the entire surface from different angles. For the test, I divided the 360° degrees positions into several scans that varied from a minimum of 5-9 scans, according to previous literature, until increasing up to 11-16. Generally, the scans' number should always be odd to overlap the last scan

[104] Some tests were carried out also on more complicated objects, such as the one performed on an Ayia Irini minotaur, (not inserted into the current research sample since it does not fall within the small human figurines group) conserved at the Cyprus Museum. Shape wise, the difficulties encountered for the digital data acquisition were quite engaging and useful for the small human statuettes digital acquisition.

with the first and cover all the surface of the object (see Amico et al. 2012:16 and Tucci et al. 2011 for different tests and results).

An important aspect of 3D digital data acquisition is maintaining a sequential workflow of steps, especially in the case of very similar objects, to optimise the acquisition time and accuracy. The 3D model's overall accuracy depends, in fact, also on the acquisition flow and the precision in overlapping areas, positions and view of the instruments. Therefore, I decided to follow a workflow that started from the 360° acquisition of the statuette standing, a 180° scan acquisition (bracket) of the top part and another one of the bottom. Occasionally, I added further single scans to cover the geometry of the artefact entirely (Figure 3.6).

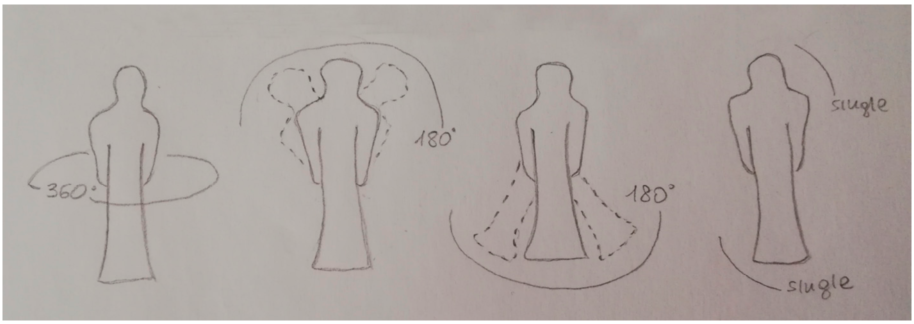

Figure 3.6
Acquisition steps: 360°, 180°, 180° and single scans (Vassallo©).

Tests for image-based documentation

I also performed various tests for the image-based 3D modelling data acquisition (Figure 3.7). Mainly, it regarded the position of the sensor with respect to the object, the environment, the lighting, and the background.

Image-based documentation requires careful planning for what concerns the sensor position with respect to the object. The technique requires a partial superimposition of the pictures. It was necessary to consider an overlap of about 60-70%, paying attention also to the shooting angle, in order for the software to apply the collinearity principle and produce a good final 3D model. To decide on the acquisition strategy, I started by positioning the object in the centre of a room and performing a 360° acquisition. The second experiment placed the object in a fixed position and made it rotate 360° on itself (thanks to a rotating table that avoided handling the artefact between each photoshoot) and having the operator in a fixed position. Eventually, I abandoned the first solution in favour of the second since elements present in the room considerably disturbed the data acquisition. The second became the standard one because it was possible to place the object inside a white light tent and indirect lights allowed to take photos in a controlled environment free from disturbing external elements. The external elements, if not adequately eliminated during data pre-processing, complicate and slow the process of data elaboration.

Other tests focused on the best background to set the statuettes on while taking photos (e.g., graph paper, white or black background). Eventually, I selected a monochrome background since it facilitated its easy and fast elimination during the post-processing.

Figure 3.7
Photogrammetry tests were performed with different lights and backgrounds at the Lund University labs (Vassallo©).

Regarding the quality of the photos, I tested other parameters. For instance, one of the most common camera issues is the ability to render the images' colours as accurately as possible. The change can happen because different light sources can give the images different colours than the original.[105] Unlike human eyes, which cannot notice the difference since they automatically adjust the sight to the light, digital cameras notice it, but they cannot adjust automatically. Therefore, the operator has to provide this information and calibrate the camera accordingly. The White Balance (WB) pre-set is the process of removing unrealistic colour casts, according to which the white appearing in the real scene should be rendered white in the photo. Usually, digital cameras present the white balance pre-set; this is enough for my research scope, and it is not necessary to deal further with colour temperature adjustments. After installing the lights, the set for the photo shooting of the artefacts, and selecting the pre-set option, it was necessary to hold a so-called

[105] A light source has a 'colour temperature', which refers to the relative warmth or coolness of white light that can give different colour to the images. For instance, fluorescent light can add a blue hue to photos, while incandescent lights can change the colours into a yellowish shade.

'white card' and photograph it as a reference. The camera records the light's colour temperature reflected from the white card and uses it as the standard for the WB setting. This option proved useful in rooms with windows and changing lights. After the tests, this was the choice for documenting the statuettes in Sweden; the photos are in JPEG format.[106] Thanks to the availability of photo post-processing professional software in Cyprus, I tested and performed the statuettes' shooting differently. I acquired the images in RAW format and then reworked them with the Lightroom software[107] to make them homogeneous in lightness and colour.

Once the tests' results were evaluated and the best solutions in terms of time, efficiency, and quality identified, I started the actual data acquisition campaign. The following parts of the chapter will present a more detailed description of the 3D digital data acquisition campaign performed at museums hosting the Ayia Irini assemblage and the creation of the 3D models. Specifically, digital acquisition occurred in two countries and four different museums because of the material's division into several locations and institutions.

3D data acquisition at Lund University Historical Museum (Lund University and Gastelyckan)

The digital data acquisition in Lund was in two different moments. The first one at the Lund University labs coincided with the test (Figure 3.5). On that occasion, in one working day, I digitally acquired two statuettes with the laser scanner and photogrammetric technique. I digitally documented the figurines using a NextEngine laser scanner, connected to a workstation Lenovo ThinkPad W540, Intel® Core™ i7-4900MQ 2.8 GHz, 32 GB RAM, Nvidia Quadro K2100M 2 GB DDR5. A first automatic alignment followed the statuettes' point cloud capture to investigate if any parts of the objects

106 If shooting in JPEG format, it is still possible to make slight white balance adjustments to the images after, but it will not be possible to make radical corrections. In this case, most of the cameras and post-processing software have auto white balance (AWB). With AWB, the camera evaluates the scene and adjusts on the best white balance to use, usually taking as a reference a neutral colour like white or grey.

107 Adobe Photoshop Lightroom is an image organisation and manipulation software developed by Adobe Systems for Windows, macOS, iOS, Android, and tvOS (Apple TV). It allows importing/saving, viewing, organizing, tagging, editing, and sharing large numbers of digital images.

were missing or if any issues during the data acquisition occurred.[108] Table 3.2 reports the digital data acquisition settings operated for this survey campaign

The photographic survey for the image-based 3D modelling technique consisted of taking pictures of the two statuettes turning 360° around them. A Canon EOS 550D with 18 MP and a 29 mm focal length allowed obtaining dense clouds with information on the RGB value. Two standing lights illuminated the scene. Since the room was a controlled environment dedicated to this kind of activity (dark room with no external lights), the results were good, and the solution was efficient. Unfortunately, because it was complicated to bring the statuettes outside of the museum due to security issues, I performed the second part of the digital data acquisition campaign at the Lund University Historical Museum's warehouses (Gastelyckan), where the items are conserved (Figure 3.8).

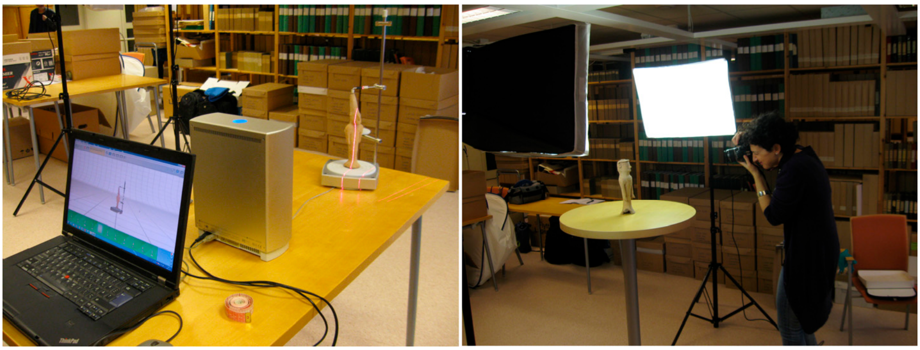

Figure 3.8
3D digital data acquisition with a laser scanner (left) and image-based 3D modelling technique (right) at Gastelyckan – LUHM (Vassallo©).

On that occasion, the other eight statuettes were 3D documented with the laser scanner and photogrammetric technique (the photographic campaign was similar to the first one).[109] The digital data acquisition of this group of statuettes was slower than the successive campaigns since various issues

[108] The automatic alignment is a first check since the post-processing phase is done later in the laboratory using, partly the proprietary software of the NextEngine (ScanStudio HD and ScanStudio HD PRO), and the open-source software (MeshLab).

[109] On that occasion, also three (3) artefacts belonging to the so-called 'large human idols' were digitally acquired. They are not included in the sample for this research, but they were taken for some tests since they are entirely made with moulds.

slowed the procedure. First, it was necessary to become familiar with the objects' various shapes and then find the best solution for acquiring the whole geometry. Given the complexity of the statuettes at surface and shape level, with many not visible areas due to some of their details (e.g., underarms area, superimposition of different parts, inner part of the tubular body), its size and its fragility (that complicated in some cases to opportunely position the item in a safe way on top of the laser scanner stand), a few scans were needed to register all facets (see Table 3.2). Moreover, the area available for digital acquisition was, unfortunately, in an open space, subjected to the passage of people and with various light sources from all around. People's movements caused both vibrations of the tool and variations of colours during the laser scanner and the photographic acquisition. In some cases, interruptions and restarting the procedure were necessary to obviate these issues. The entire survey campaign needed seven working days in total.

3D data acquisition at the Cyprus Museum (Nicosia)

The 3D data acquisition at the Cyprus Museum in Nicosia was also carried out in two different phases, according to the availability of the museum's study room. The first campaign needed seven working days, during which I digitally acquired twenty-one artefacts. The second digital data acquisition campaign required seven working days, and further twenty-one statuettes were digitised. Two NextEngine scanners connected to two HP ZBook 17 Mobile Workstations, Intel® Core™ i7-4900MQ, 2.8 GHz, 32 GB RAM, Nvidia Quadro K3100M 4 GB DDR5, to document as many statuettes as possible during the period granted for the survey (Figure 3.9).

Since the main aim of the 3D documentation was to acquire the statuettes' geometry, I tested the capture with no image texture. The results of the geometry acquisition were correct, but the lack of colour affected the post-processing. Even if the texture is low quality (the laser scanner has a low-resolution camera of 5.0 Megapixel), its presence is particularly useful during the alignment of the scans. Because of the homogeneity of the clay structure and the presence of very few reference points represented by the decorations, the alignment was very difficult. For this reason, I decided to keep acquiring the colour too. Table 3.2 reports the digital data acquisition settings operated for this campaign.

Figure 3.9
3D digital data acquisition at the Cyprus Museum was carried out with a triangulation-based laser scanner (NextEngine) (Vassallo©).

I faced various issues during the digital acquisition campaign at the Cyprus Museum's premises. First of all, the study room where I carried out the data acquisition is on a second floor with wooden pavement highly subjected to the movement of people around (inside and outside the room). In some cases, the vibrations affected the reliability and accuracy of the scans. For this reason, I had to perform new data acquisitions of the objects to avoid any alignment issues. Cyprus's extreme summer temperatures caused additional problems. Although the room was air-conditioned, in a couple of cases, the NextEngine experienced overheating, and a warning about the possible inaccuracy of the data acquisition appeared. On those occasions, I had to interrupt the digital acquisition and restart after a break to avoid any accuracy issues or failure of the scanning procedure.

I performed the photographic survey of the first documentation phase by positioning the statuettes in a white light tent and two external standing lights outside it to create a diffuse brightness on the objects (Figure 3.10). Thanks to the access granted by the Cyprus Department of Antiquities (DoA), I performed the second survey in the museum photographic room with two standing lights and a professional desk with a homogenous white background. I used a Canon EOS 6D camera with 20 MP and a 35 mm focal length to obtain dense clouds with information on the RGB value.

Figure 3.10
A photogrammetric survey carried out at the Cyprus Museum with a light tent and two side lights to illuminate the scene diffusely (left). Detail of the equipment and the photographic set (right) (Vassallo©).

3D data acquisition at Medelhavsmuseet (Stockholm)

In eight working days, I performed the 3D campaign at the Medelhavsmuseet in Stockholm.[110] Forty-eight (48) statuettes were 3D digitally acquired employing two NextEngine laser scanners (one provided with the ScanStudio standard version and the other with the HD Pro version) and photogrammetric technique. I connected the laser scanners to two workstations Lenovo ThinkPad W540, Intel® Core™ i7-4900MQ 2.8 GHz, 32 GB RAM, Nvidia Quadro K2100M 2 GB DDR5. Table 3.2 reports the digital data acquisition settings operated for this survey campaign. I used a Canon EOS 70D with 20 MP and 22-19 mm focal length for the photographic campaign. Two standing lights positioned at the sides created a homogeneous light on the objects. After the good results in Cyprus, the data acquisition was performed by staying in a fixed position in front of the statuettes and turning them to shoot all the different angles.

The museum granted three different rooms to carry out the laser scanner and the photogrammetric campaigns. I performed the laser scanner survey in two small rooms close to the Ayia Irini collection exhibition case[111] while I

[110] One week before, I visited the museum to sample the statuettes together with the museum curators and to bring part of the instruments.

[111] During the first week, I carried out the survey in a room. During the second week, due to an upcoming exhibition in that room, the museum provided another space. For this reason, I had to change all the instruments and the workspace settings. Both rooms were open to the

carried out the photogrammetric survey in an interior room of the museum. The interior room had photographic facilities (photographic table, tripods, lights) that the museum put at the disposal for the survey. Unfortunately, the room's large windows had no shutters. The striking variability and intensity of the sunlight caused variation in the photos. For this reason, I carefully evaluated light exposure during each shot. In many cases, I had to adjust the parameters or repeat documentation procedures. Overall, the documentation at the Medelhavsmuseet proved slower than expected (Figure 3.11).

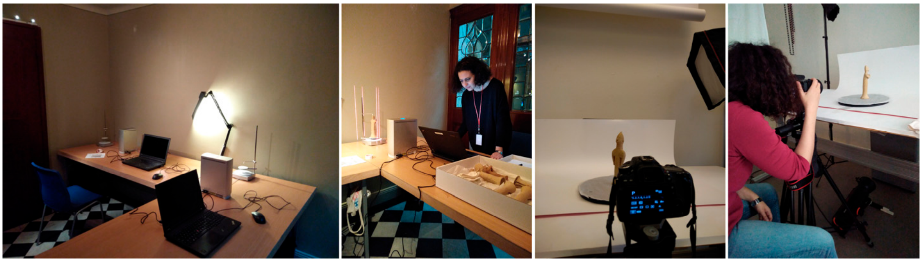

Figure 3.11
3D digital data acquisition at the Medelhavsmuseet (Vassallo©).

3D data acquisition at Malmö Konstmuseum

The last 3D data acquisition was held at the stores/laboratories of the Malmö Konstmuseum in one working day, comprehensive of the setting of the workspace (see Table 3.2). Three statuettes were 3D digitally acquired both with laser scanner and photogrammetric technique. I connected a NextEngine laser scanner to a workstation Lenovo ThinkPad W540, Intel® Core™ i7-4900MQ 2.8 GHz, 32 GB RAM, Nvidia Quadro K2100M 2 GB DDR5. I used a Canon EOS 70D with 20 MP and a 31 mm focal length for the photographic campaign and two standing lights to create a homogeneous light on the objects. The museum provided a dark room equipped with photographic tools (a photographic table and a tripod) for the photographic survey. I achieved excellent results due to the ideal setup of the room.

public and people could watch the working operations and ask questions about the ongoing research (a couple of video interviews are available). This arrangement gave life to an interesting case of community archaeology. However, in some cases, the presence of people slowed down the procedure and in other cases caused some issues in the digital acquisition process, requiring the repetition of some operations.

Table 3.2
Specifications adopted for the 3D digital data acquisition of the Ayia Irini statuettes sampled and conserved at the four hosting institutions.

Museum	LUHM (LU lab and Gastelyckan)	Cyprus Museum	Medelhavsmuseet	Malmö Konstmuseum
Instrument	NextEngine	NextEngine	NextEngine	NextEngine
No. of divisions	360/11 divisions; Bracket/11 divisions	360/11 divisions; Bracket/11 divisions 180 180 Single scan	360/11 divisions; Bracket/11 divisions	360/11 divisions; Bracket/11 divisions
Mode	Wide	Wide	Wide	Wide
Software	2.0 HD Max	2.0 HD Max / HD Pro	2.0 HD Max / HD Pro	2.0 HD Max
Object texture	Neutral	Neutral	Neutral	Neutral

3.2.2 Digital Data Post-Processing

After the digital data acquisition, I performed the data post-processing of the 3D objects' geometry. Data post-processing consists of ordering the point clouds acquired, reducing redundant and incorrect points and generating a single polygonal mesh from all the single range maps that create the model. The range maps post-processing pipeline is a long and accurate work since it requires semi-automated, manual work and precision, and it involves different steps, from editing, cleaning and aligning of the range maps to the construction of the 3D model surface and texture mapping. After importing all the range maps in dedicated software, it is possible to proceed to the removal (**data cleaning**) of the unnecessary or wrong points (**noise**) produced by the laser scanner during the data acquisition phase or not belonging to the objects scanned.[112]

The next step involves aligning all the range maps (**point cloud alignment**). This phase aims to bring all the range maps to the same reference system space and match all the parts acquired during the scans. Usually, the alignment proceeds between pairs of range maps and the common features are detected and aligned. For this reason, it is crucial during the data acquisition to overlap common areas between successive scans. The alignment procedure consists of selecting at least three/four pairs of corresponding points on two point clouds and aligning them, making sure that the results end up in a correct position and that, at the end will be

[112] It is essential to consider that all the instruments produce noise due to different factors: external (e.g. micro-vibrations, environment) and internal for the specific tool.

perfectly overlapped, with the minimum percentage of error (Russo et al. 2011: 179).

After the range maps' alignment in the same reference system, the next step consists of merging them into a single point cloud and reconstructing the surface (**scans merging**). Surface reconstruction is an important procedure since the system has to generate a single surface by elaborating an average between all the scans, to obtain a unique surface. This phase of merging should avoid performing any smoothing filter to keep the maximum reliability of the data acquired. The final step consists of the **polygonal mesh generation**, and the result depends on the accuracy of all the previous steps. In this phase, the software manages the points not correctly acquired and calculates the surface-specific parameters with the missing data points. The resulting model is an accurate mesh without holes.[113] Generally, any model presents gaps due to the hidden areas challenging to be digitally acquired.[114] The aim and use of the model always suggest if those 'holes' can be closed. That is usually not recommended in archaeology since it might introduce fake elements that can prevent the artefact's analysis and interpretation. The 3D model can now be exported in different formats, depending on the operator's choice or use.

Some geometric changes might happen during all the passages. Both scanning and post-processing techniques, during the noise reduction, the use of filters, hole filling and compression could change or eliminate significant data, at least at a micro-level (Moitinho de Almeida 2013: 105; Moitinho de Almeida & Barceló 2012: 391-392). It is important to consider all these aspects and provide transparent, standardised documentation of all the steps and intermediate results as metadata accompanying the 3D outcomes (Havemann 2012), as this research did.

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113 After creating the model, some software allows a statistical analysis of the scan results to check and compare the raw data's quality and the final mesh (Farjas et al. 2010: 11).

114 In 3D modelling, researchers call "non-manifold" the models with holes. The 3D scans registration generally produces raw data in a point cloud format. The point cloud will not form a watertight mesh. In these cases, there is a chance that models can have gaps or holes and the operator has to close them. Different reasons cause holes, both from the acquisition and the post-process phase: lack of occlusions due to the shape of the object, the specific direction and angle of the acquisition (partial covering of the geometry due to partial scanning), or the specific material of the object (e.g., reflectance, dark colour), errors in the point cloud either due to overlapping triangles during the acquisition either due to post-process faults it might happen to have noise in the data due to registration displacement (Attene et al. 2013; Biasotti et al. 2016: 34).

The final step consists of the image alignment and application to the 3D model (texture mapping). Most laser scanner devices, besides the geometry, usually also acquire the texture. In all the other cases, the solution is to acquire and apply the texture with various methods and techniques, automatized or manually achieved. In this research, due to the selected laser scanner camera limitations, the result is achieved using the textured model created through image-based modelling, then integrated with the geometry of the laser scanner for higher precision results (Xiong et al. 2009).

Post-processing of the Ayia Irini data digitally acquired with a laser scanner

Data post-processing followed each data acquisition performed on the Ayia Irini artefacts.

After the digital data acquisition operated with the laser scanner, I processed all the raw data (range maps). The files have been exported from the proprietary laser scanner format into .PLY format, to be interoperable and readable by other data processing software. For the scope, I used the open-source software MeshLab[115], which is particularly efficient for aligning the range scans and processing the meshes (Figure 3.12a). I performed the range scans data cleaning within MeshLab (elimination of the background, parts of the turning table, and gripping elements of the instrument). I performed part of the cleaning and possible repairing of the meshes applying specific filters already tested in past CH projects[116]: '*remove duplicated faces*', '*remove unreferenced vertex*', '*remove duplicated vertex*', '*remove non-manifold vertex*' and '*remove non-manifold faces*' (Amico et al. 2012:16-17; Athanasiou et al. 2013:6).

After cleaning, the second phase was to align all the range scans to create the final model. In the specific case study, the alignment process occurred through the semi-automatic identification of homologous points (**point-based registration**). As the standard method foresees, I operated the alignment of two range scans per time. For an optimal alignment, I chose more than three points in common between the two range scans. Such operation, as highlighted previously, needed to be well foreseen during the planning and data acquisition phase to avoid missing parts in the outcome. The second step

[115]. The visualisation software for data post-processing used in this thesis is the open-source software MeshLab (http://meshlab.sourceforge.net/), developed by the Visual Computing Lab, ISTI-CNR (Cignoni et al. 2008).

[116] MeshLab has several filters, and some are usually applied to Cultural Heritage objects: *Compact faces*, *Compact vertices*, *Merge Close Vertices*, *Remove duplicate vertex*, *Remove duplicate faces*, *Remove faces from non-manifold edges*, *Remove Unreferenced vertex*.

consisted of applying an iterative algorithm on all the range scans (ICP Iterative Closest Point) based on the approximate knowledge of the relative position between two consecutive range scans. I launched the automatic registration several times to redefine the alignment: the software better recognises the points, minimises the differences between all the points of the clouds and decreases the error percentage. The final stage of the procedure was the reconstruction of the unique surface (scan merging). Different filters for "Remeshing, Simplification and Reconstruction" are available in Meshlab.[117] Specifically, in this project, I performed the *Poisson Surface Reconstruction* algorithm, and I tested different parameters: the final ones used were Octree depth: 10, Solver Divide: 9.[118]

The current research created 3D models for specific geometric and shape analysis aims. Therefore accurate and high-quality meshes are needed (i.e. watertight). Nevertheless, high-resolution 3D models might be difficult to manage for some analyses due to the computation power needed. Therefore, in some specific cases, a simplification of the mesh is needed. Moreover, digitally acquired 3D models are not always ready and directly usable for further processing: this is due to geometric or topological defects and redundant points that could make the outcome heavy in terms of file size and not allow possible geometrical analysis algorithms to work properly. For these reasons, I had to apply a final 'cleaning' to the 3D models: specifically, an automatic pre-processing procedure (called GraviFix pipeline) to fix and simplify the Ayia Irini 3D models (Mortara et al. 2017). The pipeline allowed: 1) to remove mesh elements not belonging to the artefact geometry and tiny elements of the geometry that interfered with the computation of the specific geometric properties and shape analysis to be run on the surface and the geometry of the 3D models; 2) to simplify the 3D models up to three different sizes that can fit the needs of the different analysis algorithms (see Chapter 4).

Post-processing encountered some issues. In the beginning, I used a laptop whose characteristics were above the requirements needed (the graphic card had lower characteristics with respect to the needs of the software employed). Large amounts of data and the computer's low capacity slowed the process. For this reason, I had to employ the most powerful computers for the process

117 Usually, the most used filter for surface reconstruction applied to Cultural Heritage assets is the Poisson Reconstruction (Kazhdan et al. 2006).

118 Some problems were encountered with surface reconstruction. Mainly, this is a problem occurred by applying the Screened Poisson Surface Reconstruction algorithm (Kazhdan & Hoppe 2013).

to facilitate the workflow and the final result, both in terms of time and accuracy.

According to the calculation made by Russo et al. (2011: 181), the whole procedure of 3D modelling operated with active sensors is particularly long and complex, and it needed to consider a ratio of 1:5 between the 3D acquisition time (each scan) and the time dedicated to cleaning, alignment, generating the polygonal mesh and texturing. In terms of time and effort, the post-processing phase was the longest. The laser scanning 3D documentation took approximately 20 days, and its data post-processing needed 40 days.

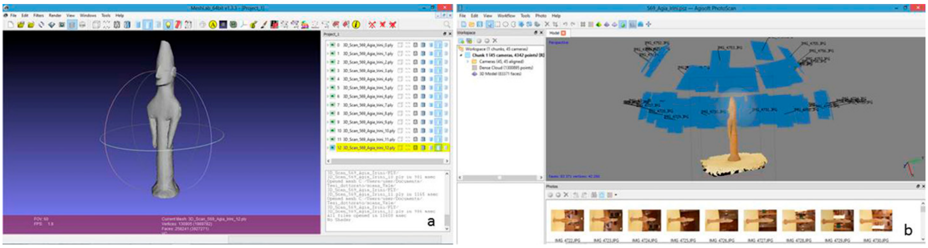

Figure 3.12
Alignment and post-processing in Meshlab of the data digitally acquired with a laser scanner (a); post-processing in Agisoft Photoscan-Metashape of the data acquired with image-based technique (b) (Vassallo©).

Post-processing of the Ayia Irini data digitally acquired with an image-based technique (Agisoft Photoscan- Metashape)

The post-processing step of the image-based technique procedure consists of importing the photographs into the chosen software, in the present study, Agisoft Photoscan-Metashape (Figure 3.12b). Initially, I performed experiments to find the best processing time and accuracy. I run the first test dividing the elaborations into sub-projects (Chunks) to simplify and lighten the data processing. This software needs high computing power, which causes a slowdown in the processing phase. The separate point clouds can be processed and subsequently aligned within the software. In the second test, I did not divide the elaborations into Chunks and tried to elaborate the final model by inserting all the images.

At last, I adopted the second solution as a standard procedure. The results appeared to be the same in terms of precision; moreover, although the computer used more time for data processing, less time was dedicated to the manual procedure of creating sub-projects and aligning the intermediate models. Nevertheless, this phase needs data preparation and ‘pre-cleaning’ (e.g., background environment, noise). Therefore, I applied the MeshLab

Mask filter to the image, eliminating the background and speeding up the procedure. The presence of a monochrome background, opportunely chosen during the data acquisition phase, could be easily eliminated.

The successive steps included the Sparse Cloud, the Dense Cloud, the Mesh, the Textured Mesh, and the final 3D Model creation. All the steps can be easily followed and automatically run since the software suggests their operative order. At the end of the pipeline, I exported the 3D models as .OBJ[119] and .PLY[120]format. Although .OBJ files are largely widespread, easily editable and transferable between applications; I also transformed them into .PLY format. Sometimes, the .OBJ format presented issues in the visualisation related to colour keeping. Indeed, in contrast to .PLY files, the .OBJ ones do not handle per-vertex colour.[121]

At the end of the procedure, the outcome is a textured 3D model. It is essential to underline that, in the beginning, the image-based 3D modelling technique aimed at improving the accuracy and precision of the geometry and the quality of the texture of the 3D models obtained with the laser scanner technique.[122] Nevertheless, the image-based 3D models provided even further

[119] This format, initially developed by Wavefront technologies, has been successively used by different 3D graphic applications. Such a format can represent 3D geometry, normals, colour, and texture. The version of this kind of file is usually ASCII, but some proprietary binary versions of .obj also exist.

[120] The .ply format, also known as the polygon file format or Stanford triangle format, derives from .obj, but its development was due to store 3D data. Specifically, .ply uses a list of flat polygons to represent objects, and such a solution serves to add extensibility capabilities and a greater amount of physical elements. The resulting file format can represent different features, such as colour and texture, transparency, surface normals, and coordinates. Both ASCII and binary versions of this kind of file are available.

[121] For the right accomplishment of the whole procedure, it is important to underline that Agisoft Photoscan-Metashape operates with the original images, and it does not allow modifying the images in any way (e.g., cropping, resizing, and rotating). Only photometric modifications that are the adjustments increasing the luminous quality of the photo, its brightness and contrast, are allowed because they do not affect reconstruction results.

[122] Limitations in the digital acquisition of some objects' geometry were experienced (e.g., the tubular bodies' inner parts of the Ayia Irini wheel-made statuettes) because some areas were challenging to be reached by the laser scanner and by the cameras. The missing parts were due to the limits of each technique. Therefore, the integration of the two types of meshes allowed repairing some of the holes. On the other hand, luckily, these are minor issues. The objects' whole geometry is complete, and the few holes in the range maps during the acquisition do not affect the analysis. The existing 'holes' were closed during the creation of watertight surfaces, and the choices taken were declared in the metadata accompanying the whole 3D documentation procedure. In general, in terms of geometry, high-quality results were reached.

qualitative and quantitative information. Therefore, I decided to use them to extract features useful to the geometric analysis (see Chapter 4).

The 3D modelling operated with a passive sensor, and the post-processing with the software selected is easier than the previous one since it follows a more automatic procedure in several passages. The image documentation required 15 days, and its data post-processing required approximately 20 days.

3.2.3 Shape analysis framework

Shape descriptors

Chapter 1 has highlighted how archaeology studies rely on direct observation of the objects and how visual perception has a fundamental role in detecting information about them (e.g., object production, the similarity with other objects). However, a qualitative procedure is not enough. It is indispensable to compare and classify the shapes, measuring and quantifying them.

Therefore, after creating the 3D models, an essential aspect of the present methodology is the shape characterisation and extraction of quantitative features useful to operate geometrical and surface analyses. These quantitative features are called **shape descriptors**, and computational methods can extract them from the 3D models. In practice, they describe specific characteristics of the geometry of an object or part of that object (e.g., surface, perimeter) through a numerical representation. These features, quantitatively represented, can be compared with the corresponding features of other objects and aimed to find similarities useful to their unambiguous classification.

Establishing which one is the information we want to find out and why, which are the shape properties of the objects under study, and which are the shape descriptors that help us to identify it, is the first step toward the quantitative and digitally assisted identification of attributes and similarities' measures useful to this research aims (Biasotti et al. 2016b: 9).

Therefore, the first step for a shape descriptor's choice, or the design, is identifying the shape properties that better characterise the material we are studying. Like any other entities around us, archaeological artefacts are complex three-dimensional objects. This complexity has to be quantified; to do so, we need more composite mathematical and geometrical measurements than those used for simpler 2D shapes (Hermon 2008). For 3D shapes, we need more inclusive descriptors, such as areas, volume, volume-to-surface ratio, 3D points, (minimal) bounding boxes, convexity, curvature, to name a few (Barceló 2010: 118-122).

Various software or computer applications can extract this geometric information from the 3D model or parts of that model with manual and automatic procedures. Then, it is possible to export those measures into various formats for elaboration and analysis (Peloso 2005: 214). Shape descriptors should have some basic characteristics such as being concise, robust, compact, easy and quick to compute and efficient to compare. They should be discriminative of the shape they represent and not subjected to similarity transformation or variances (e.g., scale, rotation or translation); they should not be affected by geometric or topological noise (e.g., acquisition noise or missing parts) or non-related details; finally, being independent respect to the type of the 3D object representation.

State of the art on Computer graphics and Shape analysis.

A method to measure similarity (or dissimilarity) between 3D models, automatically or semi-automatically, is represented by 3D shape analysis activities. The application of functions and algorithms that use descriptors allows several activities, such as retrieval of 3D objects, matching, and classification.

With the increase of 3D documentation in various fields, there has been an increase in 3D availability and, therefore, a consequent necessity for 3D similarity search, matching, and classification methods. For instance, the need for 3D shape retrieval within large databases of models or the necessity to shape comparisons became a very urgent topic in the last decades (Funkhouser et al. 2003; Tangelder & Veltkamp 2004; Tangelder & Veltkamp 2008; Bustos et al. 2005; Bustos et al. 2007; Shilane & Funkhouser 2006; Gao et al. 2010; Li et al. 2010). One of the tasks is to help search for content by similarity. A retrieval system is based on shape matching, a process of determining the similarity between two shapes (Tangelder & Veltkamp 2004). Shape matching and shape similarity are well-known and studied subjects in computer graphics and computer vision, with the development of different methods and applications, both 2D and 3D, in various fields (Tangelder & Veltkamp 2004; Del Bimbo & Pala 2006; Zhang et al. 2007; Tangelder & Veltkamp 2008; Biasotti et al. 2008a; Biasotti et al. 2008b; Martinez-Ortiz 2010:24-28, 57, Biasotti et al. 2016a; van Kaick et al. 2011; Laga et al. 2019).[123]

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[123] Some of the fields in which the shape analysis methodology can be employed are biology (Benhamou 2004), medicine (Shen & Makedon 2006; Feng et al. 2008; Žunić et al. 2010; Atmosukarto et al. 2010), engineering (Gouet-Brunet & Lameyre 2008; Huang et al. 2010,

In the last years, also in Cultural Heritage and Archaeology, shape analysis has been widely employed, and it focuses on geometric information applied to different research questions in which the shape of cultural objects (or parts of them) contributes to the identification of qualitative and quantitative information (Pintus et al. 2014; Pintus et al. 2016).[124] The aims that move those researches are various: retrieval of shapes within databases, assessing shape similarities, interpretation of material, and automatic or semi-automatic classification of artefacts. For what concerns shape retrieval, Koutsoudis et al. 2010 and Koutsoudis & Chamzas 2011 treat the combination of a few descriptors to assess the geometric similarity of the shapes within a collection of pottery vessels. A similar approach is also followed by Biasotti et al. 2014a and Biasotti et al. 2015 for shape retrieval of 3D artefacts and shape similarity assessment, taking into consideration various shape properties (both geometric and colourimetric). In the field of automatic sherds classification, Mara et al. 2004 propose a methodology based on extracting and comparing profile sections from the 3D models of vessels' fragments. Similarly, in Kampel & Sablating 2006, shape analysis is used to obtain profile sections of pottery shapes from their 3D replicas to classify and reconstruct them in a computer-assisted way.[125] Again, Karasik & Smilanski (2008) identify and compute the axis of symmetry of wheel-made ceramics to extract their mean profiles aimed at pottery analysis. Hermon et al. 2018 use the integration of 3D shape analysis and scientific visualisation approaches to investigate archaeological artefacts manufacturing by applying them to their 3D digital replicas.

Gilboa et al. 2004, driven by the awareness of a lack of quantitative criteria for classification and comparisons and the huge quantity of data to carry out a correct comparative typological analysis with traditional methods, employ mathematical and computational tools for morphological description, classification and analysis of archaeological artefacts. Kamakura et al. 2005 and Kamakura et al. 2008 use digital 3D models of historic buildings to provide information about geometrical characteristics to help archaeologists

Žunić et al. 2012), architecture, Cultural Heritage and archaeology (De Floriani & Spagnuolo 2007; Biasotti et al. 2014b).

[124] For an overview of 2D and 3D shape descriptors used in computer graphics for archaeology, see Barceló 2010: 102-108; Moitinho de Almeida 2013: 105-108; Tal 2014; EUROGRAPHICS Workshop on Graphics and Cultural Heritage-GCH proceedings (https://www.eg.org/wp/eg-events/graphics-and-cultural-heritage/).

[125] Previously, the same authors focused on the same topics for computer-aided classification for ceramics and fragments (Sablatnig & Kampel 2002; Kampel et al. 2001).

to inspect and classify objects using statistical methods, testing both supervised and unsupervised analysis. Zhang et al. applied a quantitative 3D shape comparison to Roman statue copies in 2013. Calculating the distances between the shapes, the authors propose a method based on measurable criteria for the attribution and relation between Roman copies and Greek originals. Shipton et al. (2016) propose analysing shapes variability to re-assess past studies. They use the analysis of morphometric variables to test classification systems and to identify standards and rules in the production of the material (e.g., determination of clustering and assignment to types). Bevan et al. (2014) suggest applying computer vision and 3D shape analysis to classify China's famous terracotta warriors. They identify the artisans' signatures by assessing the similarity and variability of the 3D shapes of some of their features (i.e., ears) using an iterative closest point (ICP) method. The same method is applied to Attic head vases by Trinkl et al. (2018). Finally, a machine learning and computer vision technique is proposed by Jimenez-Badillo et al. 2018 to automatically retrieve and classify 3D digital models representing Cultural Heritage objects.[126] Shelton (2000) uses a 3D morphing algorithm to analyse style variations (based on shape variations) in archaeological artefacts and facilitate their classification, enhancing the previous studies that employed clustering methods.

Other methods

Other methods are particularly popular in archaeology for studying and comparing shapes aimed at retrieving similarities and classifying archaeological finds. One of the most used is the Geometric Morphometrics (GM) technique. Beyond archaeology, other fields like anthropology and forensic investigations employ statistical shape analysis.[127]

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[126] For the use of 3D shape descriptors, computer visions and machine learning in archaeology, see also Jiménez-Badillo et al. 2010, 2013; Jiménez-Badillo & Román-Rangel 2016, 2017; Roman Rangel & Jiménez-Badillo 2015, Román-Rangel et al. 2015, 2016a, 2016b; Jiménez-Badillo & Ruiz-Correa 2017, Canul-Ku et al. 2018. Recently, emerging data-driven techniques use machine learning algorithms to create accurate shape descriptors. A survey by Rostami et al. 2019 reviewed these techniques and compared them in different criteria, also discussing advantages and disadvantages

[127] See Cardillo 2010 for applications of GM techniques in archaeology; NYCEP Morphometrics Group (http://pages.nycep.org/nmg/publications.html) for an overview of the various applications, mostly in anthropology, paleo-anthropology, physical anthropology and prehistoric archaeology (Harvati 2002; Friess et al. 2002); Ross et al. 2010 for forensics.

In the last decades, GM has evolved with respect to traditional morphometrics, overcoming the simpler concept of size variation (e.g., distances, angles, ratios) and dealing with the more informative shapes' variation (Seetah 2014). The new approach brought a 'revolution' in morphometrics (Rohlf & Marcus 1993), and together with developments in statistics, also the analysis of shapes was enhanced; moreover, in the 1980s, a change occurred, leading to the gathering of landmarks' coordinates and geometric information about their relative positions (Adams et al. 2004). Geometric morphometric methods focus on analysing 2D or 3D coordinates of specimens' points and compute any distances or angles defined by those points: landmarks or semi-landmarks[128] represent the shapes (Adams et al. 2004, Slice 2007; Elewa 2010). This technique is a powerful aid in analysing biological specimens, human remains, and specific archaeological finds characterised by symmetry. Nevertheless, regarding biological specimens, there is a difference in landmark types and a lack of easily identifiable homologous landmarks on material culture objects (Okumura & Araujo 2019). Moreover, the user has to set landmarks manually. They must be recognisable and uniform. Furthermore, the user should select the landmarks accurately to obtain the specimen's shape for replication. Another requirement is that the sample size should be three times the amount of the selected landmarks, and they have to keep the same order for every specimen (Webster & Sheets 2010; Bookstein 1991; Mitteroecker & Gunz 2009). Therefore, GM is a process of positioning landmarks and recording their coordinates manually, which raises concerns about accuracy and inter-analyst bias (Hirst et al. 2018), especially if applied to non-symmetric objects.[129]

The characteristics identified for methods like Geometric Morphometrics bring a series of disadvantages if compared with other shape analysis techniques available. For these reasons and the type of material studied, the choice fell on automatic shape analysis techniques.[130]

[128] Semi-landmarks (or sliding landmarks) can be used when the location of a landmark might not be identifiable or repeatable, such as in the case of difficult areas to capture as curves (Gunz & Mitteroecker 2013).

[129] Another problem is that linear distances are not always defined by the same landmarks making it difficult to use for comparative purposes (Adams et al. 2004).

[130] Very recent works are going towards an automatization of the GM procedure with the creation of dedicated software, such as the one presented in Herzlinger & Grosman 2018. However, still, a review of the user and some manual adjustment in the software environment is required (e.g., identifying the axis of the objects and configuration of the landmarks grid). Moreover, as also the authors underline, 'it should be noted that this automatic positioning protocol best suits artefacts whose standard archaeological positioning follows their axis of bilateral symmetry, such as bifacial tools, points,

Literature reports several shape descriptors for easily extracting basic geometric data of archaeological objects' 3D models: i.e., elongation, roundness, thickness, straightness, eccentricity, convexity, and symmetry. Often researchers use geometric parameters and ratios d as shape descriptors: e.g., the surface area to volume ratio, compactness (the ratio of the volume squared over the cube of the surface area), convex hull, Euler numbers and bounding box aspect ratio (Zhang et al. 2007). Generally, descriptors vary from histograms, matrices, and graphs to the type of information stored, such as punctual, vectors, surface, and volumetric. These methods extract geometric information and use it to accurately describe the shapes (Biasotti et al. 2016b: 10-18). According to their locality respect to the whole model, we can characterise them into local descriptors or key point-based where the analysis works on definite points (Heider et al. 2011; Tang & Godil 2012; Mikolajczyk & Schmid 2005; Guo et al. 2013; Guo et al. 2016; Savelonas et al. 2015; Smeets et al. 2013). Region-based descriptors, where the analysis focuses on parts of the object (Gal & Cohen-Or 2006; Itskovich & Tal 2011; Attene et al. 2011). Global descriptors where the analysis works on the global shape of the object (Gorisse et al. 2007; Zhang & Chen 2001). Only a few examples work instead on colour and texture information[131] (Moscoso Thompson et al. 2018).[132] In general, one single descriptor or a single class of shape descriptors might not be enough to obtain a thorough shape characterisation, and it could not be suitable for all cases. The best solution is to integrate and create composite shape descriptors' formulas (Catalano et al. 2018a; Vranić 2005; Ohbuchi & Hata 2006; Laga et al. 2006; Gal et al. 2007; Ruggeri & Saupe 2008). In this research, we extracted different shape descriptors from the 3D digital models and merged them into compliant

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arrowheads and swords'. Moreover, in the last few years, the tendency is going towards more automatic shape analysis techniques, such as machine learning procedures.

131 In general, colour and texture are attributes mostly used in 2D image recognition and retrieval (Zhang et al. 2007: 4).

132 Many existing methods are based on the description of the 3D shape through shape descriptors represented by functions describing those shapes and compared by computing the difference between their descriptors (Kazhdan et al. 2003: 2). 3D model retrieval can be built on size functions, a mathematical tool to compare shapes (Biasotti et al. 2006). Other functions used in 3D shape retrieval can be represented by 3D symmetry descriptors of a 3D model. Symmetry is recognised as having an essential role in human recognition (Attneave 1955; Vetter et al. 1992), and its use can facilitate, among others, reconstruction or classification (see Kazhdan et al. 2004 for further references and applications). 3D shape descriptors work as principal actors in many 3D shape analysis tasks (e.g., object recognition, shape segmentation and labelling, point matching, shape retrieval), and many methods have been developed and used to calculate them.

sets.[133] Table 3.3 provides an example of various descriptors cited in the literature; this doctoral research uses some of them to extract geometric information and run digital analysis (see Chapter 4).

Table 3.3
Descriptors cited in literature and used for the extraction of geometric data in the current research (Catalano et al. 2018a).

SHAPE DESCRIPTORS	FORMULA	DESCRIPTION
Elongation	$\frac{Length}{Width}$ or $\frac{MaximumDiameter}{MinimumDiameter}$	It is a simple measure obtained by the result of the ratio between the length and width of an object. The result is a measure of object elongation with a value between 0 and 1. It means that if the ratio equals 1, the object has a squared or circular shape. If the ratio decreases from 1, the object becomes more elongated.
Thickness	Shape Diameter Function (SDF)	Shape Diameter Function (SDF) can compute the thickness. It provides a stable approximation of the diameter of a 3D object with respect to a view cone centred to the surface normal (Shapira et al. 2008). The shape diameter function, calculated for each triangle of the mesh, approximates the diameter of the object in each point, following a direction that is normal to the surface. The prevalent thickness is a type of average thickness that, intuitively, gives a good approximation of it.
Eccentricity	$\frac{Axis\ length\ (minor)}{Axis\ length\ (major)}$	The ratio of the length of the minor axis to the length of the major axis of an object can compute the eccentricity. The result is a measure of the object eccentricity given as a value between 0 and 1.
Circularity or Roundness	$\frac{4Area}{\pi\rho 2}$	Circularity is how much the shape is close to a circle. The value of a circle is equal to 1, while the value of the variations from a circle is less than 1. It is based on the mathematical fact that, in a circular object with a fixed area, an increase in the length of the object causes the shape to depart from a circle (Barceló 2010: 103).

[133] A combination of software was used to extract features and compare them. For instance, MeshLab has been used for some operation of data extraction (e.g., width, height, depth, bounding box, mesh volume, and surface) and for some topological measurements (e.g., number of vertices, faces, and edges). CloudCompare (https://www.danielgm.net/cc/) has been used for some manual meshes measurements and comparisons.

SHAPE DESCRIPTORS	FORMULA	DESCRIPTION
Compactness[134]	$\frac{4\pi \cdot area}{(perimeter)^2}$ (P= perimeter of the shape)	The ratio of the area of an object to the area of a circle with the same perimeter defines the compactness. A circle is the object with the most compact shape; therefore its measure takes a maximum value of 1.
Bounding box	area (major axis length) $*$ (minor axis length)	This descriptor informs about the size of an object in terms of space it occupies. The bounding box is the smallest box that can contain the object. The minimum bounding box is the minimum area that bounds a given shape. It gives information about the proportions and volume of the object, so it can compare and cluster objects with similar dimensions. Moreover, such a criterion does not assess similarity directly, but it can be useful for identifying standards and ratios in the production of the objects.
Straightness	Principal axis	The straightness measures the distance from the principal axis of a shape. The principal axes of an object can be the segments of lines crossing each other orthogonally in the centroid of the object and representing the directions with zero cross-relation.
Euler number	Euler number = C – H C (connected components); H (holes)	The Euler number is a topological descriptor. Topological descriptors are useful for global descriptions of objects. For example, topological features include the number of holes in a region, and the number of indentations, or protrusions; another property is the number of connected components. In particular, the number of holes (H) and connected components (C) in a region can define the Euler number. Specifically, the Euler number equals the number of components minus the number of holes.

3.3 Non-invasive material analysis

The methodology developed for this research also relies on analytical methods to investigate the Ayia Irini small statuettes from a *chaîne opératoire* perspective. The examination of the material and the identification of pigments contribute to the study of archaeological artefacts. Knowing

[134] Compactness (also known as Shape Circularity) is one of the 2D descriptors extendable to 3D. The compactness measure CStd(S) provides an indication of how much a given shape differs from a circle, producing its maximal possible value of 1 if, and only if, the given shape is a circle (Martinez-Ortiz 2010: 57).

these properties and comparing them is useful in responding to specific research questions regarding the manufacturing, the materials' provenance, and the artistic and historical framework of the artefacts (Gasanova et al. 2018: 83).

Material characterisation (e.g., composition, pigment identification) can be performed through a series of instrumental analyses, more or less invasive, to determine the concentration of a chemical element or a compound and physical conditions.

Thanks to the recent advances in analytical instrumentation, almost a full picture of the archaeological materials and their properties can be obtained in a non-destructive manner preserving the integrity of the valuable and unique objects. The first step is to set up the archaeological questions and then apply the most appropriate analytical methods.

Various techniques and analytical methods are used in archaeology for this analysis (Czichos et al. 2006). For 3D digital documentation, their use is subjected to several variables. For instance, an important aspect when analysing archaeological artefacts is their integrity as a work of art; for this reason, non-destructive analyses are a necessity. Several physico-chemical analytical techniques are available to meet such needs (Madariaga 2015): X-ray fluorescence (XRF) spectroscopy (Guilherme et al. 2008); Fourier transformed infrared spectroscopy (FTIR) (Pradell et al. 2006), Raman spectrometry (Bellot-Gurlet et al. 2006), fibre optics reflectance spectroscopy (FORS), and multispectral imaging (Cosentino 2014). Beyond the non-invasiveness and non-destructiveness of the analysis, the integrity and preservation of the artefacts must also be considered. The techniques' development brought to the portability of the tools, facilitating the measurements on-site and speeding the operation without the need to move fragile artefacts to external laboratories for their analysis.

Materials inform choices about tools: where, when, and how to use them. It is important to consider the type of material we will analyse and the reactions to one specific technique with respect to another. For example, the ability of XRF to give information on inner layers, while visible light of FORS cannot reach, could be an aspect of the choice of the first technique with respect to the second. On the contrary, the fact that it is impossible to control the X-ray beam's depth precisely is an aspect to consider in interpreting the results. Only a previous knowledge of the material and the general composition of decorations (e.g., the layers which the decoration is composed of: the support material, the presence of slipware layer, and the pigments layer) can lead to the 'best' technique to choose (Gasanova et al. 2018).

In brief, it is crucial to identify which analytical methods are more appropriate for a specific artefact or study. Also, integrating different techniques is optimal in this case since every technique can have advantages and disadvantages. On the one hand, the combination solves issues connected to the limitations of one technique with respect to another. On the other hand, different techniques can influence their performances. In general, combining two or more techniques allows for validating and complementing the results (Gasanova et al. 2018: 86).

Various non-invasive techniques can be employed to identify the characteristics previously mentioned. For instance, scholars use XRF very broadly in Cultural Heritage and Archaeology (Shackley 2011) in several studies on archaeological materials such as metals/alloys (Charalambous et al. 2014), pottery and ceramic analyses (Charalambous et al. 2013; Dikomitou-Eliadou & Georgiou 2017), and obsidian sourcing examination (Craig et al. 2007; Morgan 2015; Moutsiou 2019). One of the most interesting applications for this doctoral research is the identification of pigments and inorganic constituents of decorations on Cultural Heritage artefacts (Gasanova et al. 2017; Gasanova et al. 2018).[135] This technique can identify each pigment by its major chemical elements: e.g., red ochre by the presence of Fe (iron), yellow orpiment by the presence of As (arsenic), and blue smalt by the presence of Co (cobalt). This chemical characterisation allows identifying analytical descriptors useful to understand better the technology, modes of production and material provenance. Specifically, the trace elements might hint at the provenance of the pigments and the artefacts' classification. For this reason, this part of the study focuses on the Ayia Irini statuettes' characterisation of polychromy remains by integrating various techniques. Due to the uniqueness of these objects, the impossibility of micro-sampling dictated the decision to employ non-destructive analysis (Gasanova et al. 2018: 83, 87). Moreover, their analysis required *in situ* measurements with portable equipment to maintain their preservation status. Thus, the Ayia Irini statuettes' material properties have been analysed by combining digital microscopy as a preliminary step and X-Ray Fluorescence spectroscopy analysis, which allowed a more in-depth examination.

[135] Pigments can largely be identified based on their qualitative elemental composition through non-invasive techniques (spectral data can show the qualitative composition of the pigments investigated).

Digital microscopy and X-Ray Fluorescence Spectroscopy (XRF)

Digital microscopy is a category of characterisation techniques that probe and map a material's surface and sub-surface structure. Microscopy observations allow studying, characterising and documenting the morphology of various archaeological materials. It is also a useful tool to observe the colour of pigment particles, their size and shape, allowing one to view the invisible to the resolution range of the normal naked eye. Optical (or light) microscopy uses visible light and a system of lenses to magnify images of small objects: passing visible light is transmitted to or reflected from the observed sample through lenses to have a magnified view. Digital microscopy is the digital version of traditional optical microscopy that uses optics and a digital camera to visualise the areas analysed as images on a monitor or computer.

Spectroscopy is an analytical tool based on the interaction of various types of radiation with matter. Depending on the frequency/wavelength of the radiation source and how it interacts with the matter, one can distinguish numerous modifications of this method.[136] XRF is a method of elemental analysis that gives information on the presence of chemical elements ranging from the low-Z (Mg, magnesium) to heavy elements (U, uranium) and gives the possibility to analyse and trace elements both qualitatively and quantitatively. The high-energy X-rays excite the sample atoms, producing the emission of characteristic photons with specific energy related to the atomic number Z of each element (according to Moseley's law). In this way, the energy/wavelength of the emitted photon allows identifying the chemical elements, i.e. performing qualitative analyses. At the same time, measuring the number of emitted photons allows performing a quantitative analysis (Streli et al. 2017: 707-715). A sample is placed a few centimetres away from the radiation source, not causing any harm to the object, provided reasonable experimental conditions. At the same time, due to the penetrative nature of X-rays, XRF analysis gives information not only on the uppermost layer but also on the lower layers. Thus, this technique allows us to obtain information on the chemical elements present in different layers of the sample.

Analytical investigation at the Cyprus Museum

Due to the availability of instruments for analytical investigation and related field experts at the CyI, we performed non-destructive physico-chemical analyses on some of the Ayia Irini small statuettes conserved at the Cyprus

[136] The most widely used methods in the field of archaeology include, but not limited to: Visible light reflectance spectroscopy, Infrared spectroscopy, X-Ray Fluorescence spectroscopy, Raman spectroscopy.

Museum. Specifically, we documented six statuettes with analytical methods and characterised their pigments.

For an initial diagnostic examination, we operated a non-destructive observation under ultraviolet light (UV) with a Blacklight set (15 W, 46 cm, range UVA 300–400 nm, peak at 370 nm). The surface of the sampled statuettes was analysed using a Hirox KH-8700 digital microscope. Selected spots were photographed at various magnifications (×35–×2500) according to the target, using the dual illumination revolver zoom lenses. Successively, we used a portable XRF for the analysis of specific areas on the selected figurines with an ARTAX-200 μXRF spectrometer equipped with a molybdenum X-ray tube, an integrated CCD camera with sample illumination and laser spot, a silicon drift detector with a resolution of <150 eV and a 0.65 mm2 collimator. We operated the X-ray tube at 30 kV and 400 μA with an integration time of 180 s. We performed all XRF with a Mo filter and a He flush at the pressure of 3 bars to facilitate the measurements of the low-Z elements. We created the energy to channel calibration with a bronze standard, using the Cu- and Sn-Kα lines; for the FWHM calibration, we used the Mn-Kα line of a manganese standard. The treatment of XRF spectra was performed using OriginPro 2015 software. Since the analysed objects are part of the permanent exhibition and most are non-movable, we carried out all the data acquisition *in situ* at the exhibition rooms of the Cyprus Museum. We needed six working days for data documentation and six working days for data interpretation.

3.4 Semantic representation

In this thesis, I use the term "digital *corpus*" to identify the digital collection of the data created by this research, semantically structured and standardised. The standardisation relies on various semantic tools, which aim to facilitate data analysis and interpretation combined with the geometric and analytical approach.

The distinct but complementary aspects, geometric, analytic and semantic, are at the base of the methodology proposed. On the one hand, as already explained, geometry is fundamental for identifying shape descriptors to apply shape analysis to the 3D representation of the artefacts under study. At the same time, analytic investigation determines the identification of chemical information to characterise the material. On the other hand, semantics is necessary for standardised description and management of the artefacts (and their related data). Integrating all these aspects is useful for performing various classificatory analyses (e.g., geometric and chemical quantification of features, identification and comparison of similar geometries and patterns). Eventually, by relating geometrical analysis and analytical investigation results with semantics, it is possible to find features and properties which, if used in the reasoning process, help respond to this study's archaeological questions. The following section of the chapter is therefore dedicated to semantics and the development and use of specific tools. The proposed methodology integrates them for data standardisation and, consequently, classification. Specifically, a vocabulary/terminology (see 3.4.1) and a metadata-ontology system (see 3.4.2) are developed and used as reasoning tools within the methodology. The vocabulary/terminology, with its comprehensive and standardised description of the artefacts, is a first step of the classification clustering; the metadata-ontological system makes coherent the information coming from different disciplines and makes them able to communicate.

3.4.1 Partonomy[137]

Terminology and classification: an introduction

As mentioned in Chapter 1, coroplastic classification and terminology are hotly debated topics. Literature reports the need for a common, recognised terminology (Muller 1997b: 437 *et seq*.; Cantone 2014: 8), which, to date, is still missing (Muller & Uhlenbrock 2020).

When scholars started using punch-cards and computers in archaeology, Jean-Claude Gardin was one of the first to establish descriptive standards for archaeological material. Differently from the approach of his contemporary scholars, who looked at the topic only from an IT application point of view, he also addressed the linguistic/semiotic question. Mainly, he investigated

[137] The organisation of the concepts into part-of hierarchies is also known as meronomy (Veltman 2004: 20, 69; Hyvonen 2012: 91) from the ancient Greek word μέρος (part). In this thesis, the term partonomy is preferred to align it to work carried out within the GRAVITATE project (Philips et al. 2016). This part of the research, specifically called Cultural Heritage Artefact Partonomy (CHAP), benefits of the collaboration with IMATI-CNR, Istituto di Matematica Applicata e Tecnologie Informatiche Enrico Magenes, Consiglio Nazionale delle Ricerche, Genova (Italy). The research collaboration resulted in two publications (Catalano et al. 2018b; Catalano et al. 2020) to which I remand for a more detailed description. Here, I summarise the work done and I integrate it with some updates.

how to express data to be stored and handled with computers for analysis (Gardin 1967).

Likely, the approach developed for this part of the thesis moves from the opinion that the analysis and interpretation (connected to classification) of archaeological material has to start from the establishment of well-defined features: first at the semantic level (structured vocabulary that avoids ambiguities) and then at IT structural level (segmentation and hierarchies where possible). Such an approach implies, as a correlated element, the addition of metric/measure/rules in a structured description. Consequently, integrating these elements allows a descriptive structure that, opportunely integrated into a computer/database system, may support the automatic generation of types and typologies. Indeed, classification can result from: 1) a selection of well-defined features and 2) an ordering of those features into a hierarchy.

Taking into account Gardin's approach and the works carried out on the topic for future perspectives (Catalano et al. 2018; Catalano et al. 2017; Foka et al. 2020:1-2)[138], this part of the research focuses primarily on the first level, that is developing a structured vocabulary/terminology of the artefacts and their parts to support, within the proposed methodology, a semi-structured classification.

Archaeological documentation is typically characterised by describing the material through 'unstructured' texts, whether published several years ago or nowadays. The term 'unstructured' is intended for all traditional descriptions usually available under texts, catalogues, and excavation diaries. For example, the description of a statuette from Ayia Irini can be as follows (Figure 3.13):

> "Statuette with body as No. 52, moulded, ovoid, rather triangular head, put in separately; slightly sloping forehead; curved, projecting nose; rather thin lips; rounded chin; narrow, lancet-shaped eyes with lids and eyebrows in relief; large ears provided with large earrings; hair in compact mass down back of the head and along sides, straight shawl draped over shoulders. Hair and eyes painted black; horizontal lines on shawl; vertical lines along sides of body; transverse lines at waist. Height 21.4" (Gjerstad et al. 1935: 678, n. 83).

[138] Looking into the future and to the semantic web, Foka et al. (2020) underline how technologies can present limitations and how the use of common global vocabularies, and ontologies, can provide proper support to obviate those limitations. In the same direction, Catalano et al. (2018) underline how geometric data can be made accessible and retrievable thanks to semantic approaches. In the future, the possibility of including the semantic tools developed in this study in a semantic database will guarantee a development of this research in a broader context.

The traditional practice is to describe the artefacts giving information on the parts that constitute the whole: although information regarding shape, decoration, material, and measures might follow discretionary choices. Each part's description approximates shapes (e.g., 'rather triangular', 'curved', 'rounded', and 'lancet-shaped'). Texts do not specify which dimension has been measured and its exact extension on the object (i.e., a measure of the head's height is given, but where the head starts and finishes?). Similarly, they do not provide specific information about decorations and colours; sometimes, the documentation informs approximately about them (e.g., 'reddish', 'light red', 'dark red'), not detailing, for instance, their composition. Moreover, such descriptions do not provide explicit information regarding the relations among the parts, things which only the more or less specific knowledge of the reader can infer.[139]

[139] On the contrary, in science, the 'unsystematic' descriptions have been substituted or transformed into well-structured taxonomies (e.g., plants' structure, animals' body anatomy) since quite a long time, and classifications are systematised formalising the relations between parts and wholes (Johansson & Lynøe 2008: 401). Moreover, such documentation has become extensively digital.

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splayed base; flattened breast; square head with pinched nose, pellet ears; short, rounded beard, soft, conical helmet. Black, encircling line round helmet; face and ears painted red; black eyes, eyebrows, beard, and faint traces of black on hair; black border at the base. Red-brown clay; light slip. Height 24.5. L 11. On top of No. 81.

81. Statuette, as No 80, but with longer, narrow beard; black, encircling lines round helmet crossed by four vertical lines; hair marked by small, vertical lines encircling head; large eyes and plain, black beard, horizontal line over breast and shoulder just below neck; band of ladder-pattern along arms and along sides of body; girdle around waist consisting of horizontal and vertical lines crossing each other; line round neck supporting a round dot suggesting a necklace with a pendant; traces of colour on base. Height 25.2. L 11. 97.5.

82. Statuette, as No. 80, but with triangular, rounded beard, black, encircling line round base of helmet, face, neck, and lower arms painted red, eyes, eyebrows, beard, and hair painted black; black, transverse lines at elbows. Height 25.2 L 11. 97.5.

83. Statuette with body as No. 52; moulded, ovoid, rather triangular head, put in separately; slightly sloping forehead; curved, projecting nose; rather thin lips; rounded chin; narrow, lancet-shaped eyes with lids and eyebrows in relief; large ears provided with large earrings; hair in compact mass down back of the head and along sides, straight shawl draped over shoulders Hair and eyes painted black; horizontal lines on shawl; vertical lines along sides of body; transverse lines at waist. Height 21.4. L 11. 97 5.

84. Statuette, as No. 79. Height 23.8. L 11. 97.5

85. Statuette, as No. 83; painted chin indicating beard; band of ladder-pattern along shoulders, black neck-line; ladder-pattern along sides of body and at waist.

91. Statuette, as No. 56. Height 14 6 M 8. 102 7.

92. Statuette, as No 52; shorter hair; both arms bent over breast holding tympanon. Hair, eyes, and chin painted black (indicating beard); black neck-line; bands of ladder-pattern along sides of body and round waist; black lines along arms; encircling, black line round base Lower part of body broken; part of base missing. Height 19.1. L 9 93.6.

93. Fragment of statuette, as No. 269. Face details, top of helmet, r. arm, lower part of l. arm, lower part of body missing. Height 12.2 L 9. 93 6.

94 Statuette, as No 52. Body decorated with angular neck-lines; black lines along shoulders; bands of ladder-pattern along sides of body; transverse lines at waist. Light slip. Height 19 8. L 9. 93.6.

95. Statuette, as No. 79; trapezoid head; very short beard; conical helmet with top bent forwards. Reddish slip. Height 20.4 L 9. 93.6.

96. Statuette, as No 86; rather long, rounded beard; both arms bent over breast holding a quadruped. Hair, eyes, and beard painted black; black neck-lines; horizontal lines along shoulders; vertical lines along sides of body, horizontal line at waist; encircling band round base, eyes of quadruped painted. Light slip. Height 18.1. L 9. 93 6.

97. Statuette, as No. 79. Light slip. Height 22.2. L 9. 93.6.

98. Statuette, as No. 79, but with very short beard. Left arm and neck broken. Red clay; red slip. Height 21.4. L 9. 93 6.

99. Statuette, as No. 96; bands of ladder-pattern along sides of body, and around waist. Height 20.7. L 9. 93.6.

100. Statuette, as No. 79. Broken at top, neck, arms, and waist. Part of helmet and r. arm missing. Height 20.7. L 9. 93.6.

101. Statuette, as No. 92. Hair, eyes, and chin painted

Figure 3.13
Traditional 'unstructured' archaeological description of Ayia Irini finds (Gjersad et al. 1935: 678).

Consequently, the first step is to extract information from the available 'unstructured' documentation in order to:

- provide a detailed semantic and structured description of each object;
- formalise the relationships between the parts of each object (partonomy);
- integrate this formalised description (the partonomy) with 3D and analytical descriptors as support to accomplish the research aims of this study.

The main point is to explore documentation, considering the artefacts not only as entire objects but also including all the interesting features from an interpretative perspective (their components and measurements).

This kind of analysis is usually applied to the study and representation of ancient buildings; for example, it is used to identify single elements, relationships that occur between parts, and to define underpinning volumes (Manferdini et al. 2008; Quintrand et al. 1985; Tzonis & Lefraive 1986; Gaiani 1999; De Luca et al. 2007; Attene et al. 2007; Emgård & Zlatanova 2007; Müller et al. 2006). We can speak of parts and parthood, which is not only a definition of the parts as mere components but also as components that have relationships.[140] The de-composition principle, from the whole to its parts, is applied to the digital model and gives life to a 3D shape de-composition[141] (Varzi 2007; Ronzino et al. 2016, Ronzino 2015). Organising the information in a structured way allows useful details in analysing the artefacts. This "semantic classification", as named by Manferdini et al. (2008)[142], helps to identify shape-elements, function, and production procedures. This research uses that approach as identification of "before" and "after" or "production stratigraphy", supporting the interpretation of the artefact's manufacture (e.g., common hands).

Terminologies, vocabularies and thesauri: a state of the art

Before the Ayia Irini documentation standardisation, we reviewed the existing vocabularies and thesauri already developed to serve archaeological frames, particularly coroplastic. Various institutions and research projects in different Cultural Heritage domains developed numerous examples of vocabularies and thesauri. Such tools have been developed to serve the general frames of digital libraries and repositories (e.g., to document physical and digital items) and facilitate several activities within them (e.g., through Linked Data). Briefly (for a complete discussion, see Catalano et al. 2020: 3-4), some of the vocabularies reviewed cover subjects within the domain of art, architecture and archaeology as the Getty Art & Architecture Thesaurus (AAT)[143] built on terms hierarchically connected, and broad archaeological

[140] Smid affirms that "*a statue is different from its clay because the clay existed as an unmodeled lump before the statue*" (Smid 2017: 1-2). Such an interesting statement, connected to the philosophical investigation about the way an object is related to its parts, well introduces the concept that objects are composed of other objects or parts, and there are relations between the parts and between the parts and the whole.

[141] see also Barceló 2010:132

[142] For the cited authors, the semantic classification is a way to better organise the digital buildings' documentation with 3D models and databases. The concept follows the so-called shape grammar, developed in the late 1970s (Stiny 1975; Stiny & Mitchell 1979; Stiny 1980).

[143] http://www.getty.edu/research/tools/vocabularies/aat/

terms for movable cultural heritage and archaeological finds as the ICCD[144]/VAST-Lab[145] Thesaurus RA - Strumenti terminologici Scheda RA Reperti Archeologici[146] (Felicetti et al. 2015), or specific subjects like the EAGLE thesaurus[147] (Evangelisti et al. 2014) dedicated to epigraphy and composed of a set of authority list and controlled terms; some thesauri describe the material or the technique used, with a system of controlled terms structured in a hierarchical way, such as the one of the British Museum (BM) [148] (Collection Trust 1997).

Nevertheless, the review has revealed specific lacks regarding coroplastic. Almost twenty years ago, Arthur Muller underlined the necessity of a common vocabulary and established a lexicon to describe and articulate all phases of mass or derivative production (Muller 1997b: 438).[149] During the same years, ICCD developed a vocabulary, 'RA Coroplastica', dedicated to coroplastic for descriptive aims (Auer et al. 1998: 10).[150]: ICCD created the vocabulary starting from real artefacts and domain literature: nevertheless, many of the terms are related to specific typologies and proper names, which are less general and point to specific types of objects (e.g., anthemion - type Andren 477).

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144 http://www.iccd.beniculturali.it/

145 http://vast-lab.org/

146 http://vast-lab.org/thesaurus/ra/vocab/. This vocabulary also includes some terms of the Getty AAT.

147 https://www.eagle-network.eu/resources/vocabularies/. The terms are related to the contents and to the various descriptive fields present in the EAGLE Metadata Model, also developed within the project and further mapped to CIDOC CRM (Liuzzo et al. 2014).

148 https://collectionstrust.org.uk/terminologies/

149 A more recent attempt aimed at updating the "Lexicon" proposed by Muller (Muller 1997b) with improvement in definitions and addition of some categories is proposed within the works of the ACoST (Muller & Uhlenbrock 2015). Nevertheless, the vocabulary follows the usual traditional criteria and it is not standardised, and at the moment a digital version of the vocabulary is still unpublished.

150 The Italian Central Institute for the Catalogue and Documentation (ICCD) created some thesauri and Guidelines. These resources provide information about the use of terminology and vocabularies as well as guidelines: they include a list of terms, descriptions and other useful information for artefacts' cataloguing. Moreover, they are organised in part for the 'Object definition dictionary' and then subdivisions related to specific items (e.g. 'vocabulary of coroplastic', 'vocabulary of mosaics', 'vocabulary of glasses', 'vocabulary of materials'). Unfortunately, only the 'Object definition dictionary' provides structured information for each entry. A recent attempt to a semi-automatic Archaeological Italian Electronic Dictionary starting from these resources is developed by di Buono (2015: 42).

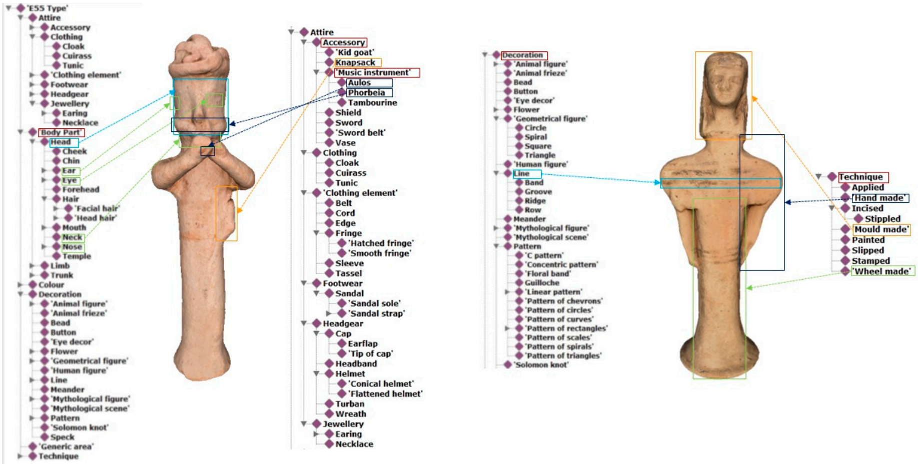


Figure 3.14
Relations and hierarchies as described through partonomy (Vassallo©).

Although they are about coroplastic, the last cited cases do not present a digitally structured formalisation and do not dwell on the partonomic composition of the objects. The presence in coroplastic of numerous decorative and structural features, the specific postures and all their combinations require a coherent and hierarchical description, which is missing and would advance the investigation of this specific archaeological material.

The review revealed the need for a dedicated vocabulary, formalised and semantically expressed. In this perspective, the partonomy proposed here serves as a controlled vocabulary, allowing subdividing and describing the artefacts into components presenting hierarchical relationships (Figure 3.14) for any typical interpretative operation, such as supporting the archaeological classification (e.g., digitally assisted classification and clustering).

The partonomy's aim is the documentation and semantic enrichment of the resources and all the artefact's information. It is a tool designed to complement the traditional textual description. Indeed, the partonomy, beyond the qualitative semantic description of the geometric parts and the decorative features, also includes the digital parts' quantitative information. The proposed methodology supports specific goals such as archaeological interpretation and assisted classification, focussing on the artefacts and their digital counterparts. Using a taxonomy expressing a partonomy helps to perform combined queries that include geometrical and decorative features.

Therefore, such a partonomy is useful to establish a granular description and their consequent similarities.

Construction of the partonomy

According to the methodology commonly used for constructing vocabularies and following the state-of-the-art guidelines for bottom-up approaches (Catalano et al. 2020: 3-4; Ferdani et al. 2014: 8; Aaberge & Akerkar 2012), we built the partonomy manually. The procedure consisted of extracting terms, keywords and concepts from a corpus of texts -i.e. archaeological publications, catalogues, and excavation reports- (Gjerstad et al. 1935; Karageorghis 1995; Fourrier 2007), curatorial documentation, and from the archaeological analysis of the objects themselves. We conducted a peer-review discussion among archaeologists regarding the best terms for each category and the relative definition. The methodological approach involved revising each term, its corresponding definition and the final approval of the lemma (term and definition).

Finally, we created a vocabulary with consistently structured terms (corresponding to parts) and related between them. The partonomy describes and structures the Ayia Irini artefacts formally, subdividing them into hierarchical components which allow the creation of many-to-many relations between the terms (so far, only the body parts present a hierarchical structure). Nevertheless, the proposed approach is general and can be applied to different contexts specifically dedicated to coroplastic since it can support any archaeological research where the goal is an extensive digital documentation of tangible findings, including quantitative attributes. The structure could extend to other coroplastic representations, chronological periods and geographical areas. Some technical precautions allow for future developments towards the automation of the process if integrated within a database through a semantic organisation system (e.g., ontology). Therefore, the structure of the partonomy has been edited in Protégé[151] and modelled as a SKOS (Simple Knowledge Organisation System)[152] hierarchical vocabulary to keep it independent of the semantic scheme.

Structure of the partonomy

In this research, the various features and elements characterising the coroplastic artefacts need a standardised description to support research in

[151] https://protege.stanford.edu/

[152] https://www.w3.org/2004/02/skos/

identifying similarities for classification aims. Therefore, the partonomy consists of classes that semantically describe all the parts of the Ayia Irini statuettes and their hierarchical relations. A few central concepts, which play an important role in the morphological and colour characterisation of statuettes, organise the structure of the partonomy: *Body part*, *Attire*, *Decoration*, *Colour*, and *Technique*. A further class, *Generic Area* annotates regions where undefined features are present (e.g., the presence of faded colour, which creates a not defined area on the object and which would deserve additional investigation). Figure 3.15 shows the general structure of the partonomy. The *Body part* class is an extensive hierarchical description of anatomical constituents, including some specific characterisations (e.g., the hairstyle, the pose of hands). The second key concept is related to *Attire*, which classifies all the possible accessories of the items investigated: the set of accessories spans from musical instruments, small offered animals and weapons to elements of garment and jewellery to cover the features represented in the artefacts of the case studies, but also typical of other coroplastic productions. Another class represents the *Decorations*, which presents extensive work on distinguishing geometric figures, such as single lines, from patterns of lines. Finally, a component is devoted to *Colour* and another to the *Technique* adopted to create the artefacts. Their simplified hierarchy currently allows integration with other recognised thesauri (e.g., the British Museum *thesaurus* on techniques).

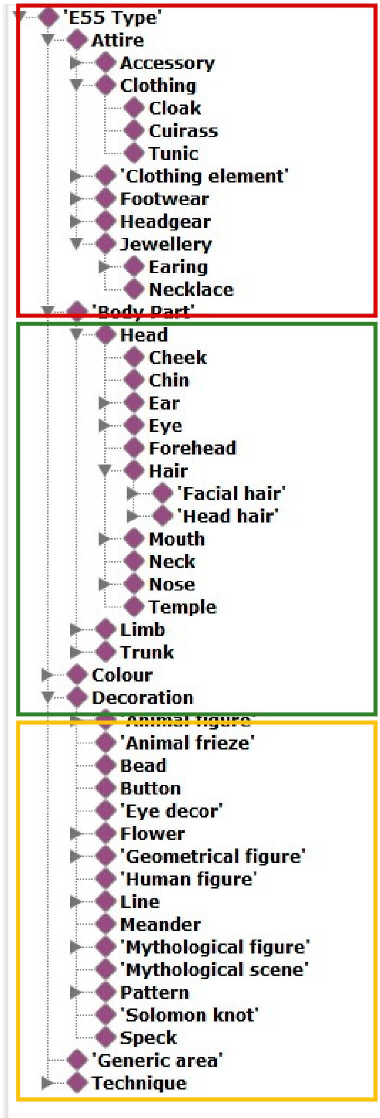


Figure 3.15
Overview of the Cultural Heritage Artefact Partonomy structure (Vassallo©).

3.4.2 Semantic modelling for data integration

Following the extensive use of digital technologies in archaeology, the amount of data available has grown significantly, producing complex 2D and 3D digital assets since they bring along multiple pieces of information (e.g., about the object, the digital provenance). Therefore, we can consider a digital model as an information container of several data coming from different fields of knowledge. For this reason, the creation of digital models has to contemplate also the documentation of their production. Knowing how to manage and preserve that information is fundamental to having a scientific instrument that enables understanding, interpreting and preserving it (Vassallo et al. 2006).

Thorough documentation is fundamental for transparency. Data transparency is at the base of knowledge (Vassallo et al. 2006) since it allows accessing information and interacting with it dynamically. An open, accessible and transparent approach permits to go through all data production steps and make the users able to understand, interpret or re-use data. As in the scientific method, digital data allows for checking the results (Forte & Pescarin 2012).

At the beginning of the 21st century, scholars started to consider the concept of transparency as an important aspect of the Virtual Archaeology interpretative process. Every model should be "transparent" and give information about its reconstruction procedure, allowing it to go back to the raw data and verify the entire process (Forte 2000). It was only in 2006 that these principles were established and internationally recognised with the London Charter[153] (Beacham et al. 2006) and successively with the Sevilla Charter that implemented the first one in digital archaeology (Lopez-Menchero & Grande 2011; Grande & Lopez-Menchero 2011; Vico & Vassallo 2013).[154]

The concept of paradata, as elaborated in the charters, influences transparency and plays a significant role in this research. The term 'paradata' means "information about the human process of understanding and interpretation of data objects". Therefore, it is paramount to document the 'paradata' along with the digital representation (Frisher 2012) to trace all the production workflow and access raw data for further research and interpretations (Vico & Vassallo 2013). Paradata is necessary to trace the

153 The London Charter 2009 (www.londoncharter.org/).

154http://www.arqueologiavirtual.com/carta/wp-content/uploads/2012/03/BORRADOR-FINAL-FINAL-DRAFT.pdf production history and the digital provenance, tracking every technical "datum" from all the processing steps until its origin (Havemann 2012).

These data are challenging to manage and need a structured arrangement. For this reason, for what concerns the data related to the 3D documentation process of the current research, I created a structure that would provide transparent access and organisation of the information.[155]

A first step towards standardisation: organisation of the 3D modelling documentation

An Excel file is employed to document all the data and paradata related to the whole digital acquisition and post-processing phase: parameters, digital acquisition positions, number of scans operated, number of images taken, and areas investigated. The information can be divided into different sections, summarised as follows: *Archaeological Object*; *3D Digital Data Acquisition*; *3D Digital Data Post-processing*; *3D outcome*. The *Archaeological Object* section gathers information regarding the archaeological artefact, such as the inventory number and its image or drawing, for easy identification. The *3D Digital Data Acquisition* section records information regarding the technique and sensors used, the software employed, the tool's settings and the information related to the choices performed. The *3D Digital Data Post-processing* section gathers all data concerning the 3D digital data post-processing related to the techniques employed. The fields trace the entire procedure for the laser scanner method, providing information about the scans' alignment and the filters used. The same data structure gathers the information produced by the image-based post-processing pipeline: the camera's settings and choices made before and during the acquisition phase. Even though the latter method implies a fixed pipeline, this thesis documents all the chosen settings since they are not accessible after the model creation, preventing a revision of the procedure. The last section gives information about dimensions of the 3D outcomes in file weight and the number of

[155] It has been discussed the importance of the different documentation aspects (digital and non-digital) and its value in the various phases of the proposed research methodology. Since documentation is the process of recording information for reliability and ease of sharing that information, all the types of material under study must be documented consistently, using recognised standards, common structures, and homogeneous terminologies. According to the UNESCO guidelines (Stiff 2007), writing a textual description of an object's shape and appearance is highly recommended, possibly including measures. As also demonstrated in Chapter 2 by explaining the case study and here in the current chapter regarding its documentation and description, the typical approach in archaeology is mainly qualitative and, as such, can be very rich but more subjective and affected by ambiguities.

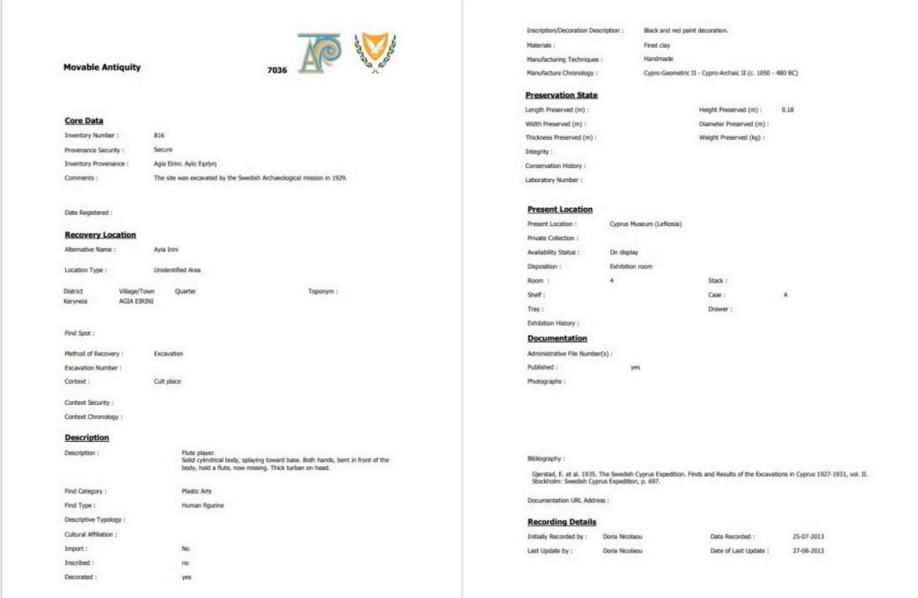
vertices and faces. Therefore, the information in the file describes the entire 3D modelling procedure and its results in a more structured manner.

Information about the Ayia Irini assemblage in different museum archives

Another critical aspect of the Ayia Irini assemblage is that, beyond the already mentioned 'unstructured' texts, the different hosting museums provide different kinds of data descriptions in their catalogues and databases. Therefore, it is necessary to assess these catalogues to verify the main relevant information, understand the diversity of those descriptions and eventually plan the development of a common semantic framework.[156]

The fact that the pieces are housed in multiple museums means that object descriptions vary considerably. The SCE publication is the core of the information (Gjerstad et al. 1935), but the host institutions introduce other descriptive fields according to their documentation approach and conservation needs. Moreover, within these descriptions, in some cases, additional material is provided; in other cases, some information is entirely missing. Therefore, depending on the aims they were built for, this documentation is variable in quality and level of detail. Quality and variance in the descriptions might also have an impact on the whole documentation of the material. For instance, the issue is quite evident in the terminologies employed by the different institutions (sometimes even by the archaeologists describing the same object or features).

[156] How museums face data standardisation issues? Do they do it? If yes, what are the solutions adopted? Usually, the common practice to address these kinds of questions is to perform a Data Management Plan survey to investigate the solutions adopted by each institution (e.g., quantity of data, type of data, metadata formats/schemas/ontologies and controlled vocabularies used, use of PIDs, subjects and languages, data storage service). For a reference to the methodology, see Vassallo & Felicetti 2020.



Movable Antiquity 7036

Core Data

Inventory Number : 816
Provenance Security : Secure
Inventory Provenance : Agia Eirini. Αγία Ειρήνη
Comments : The site was excavated by the Swedish Archaeological mission in 1929.

Date Registered :

Recovery Location

Alternative Name : Ayia Irini

Location Type : Unidentified Area

District	Village/Town	Quarter	Toponym :
Keryneia	AGIA EIRINI		

Find Spot :

Method of Recovery : Excavation
Excavation Number :
Context : Cult place

Context Security :
Context Chronology :

Description

Description : Flute player.
Solid cylindrical body, splaying toward base. Both hands, bent in front of the body, hold a flute, now missing. Thick turban on head.

Find Category : Plastic Arts
Find Type : Human figurine
Descriptive Typology :
Cultural Affiliation :
Import : No
Inscribed : no
Decorated : yes

Inscription/Decoration Description : Black and red paint decoration.
Materials : Fired clay
Manufacturing Techniques : Handmade
Manufacture Chronology : Cypro-Geometric II - Cypro-Archaic II (c. 1050 - 480 BC)

Preservation State

Length Preserved (m) : Height Preserved (m) : 0.18
Width Preserved (m) : Diameter Preserved (m) :
Thickness Preserved (m) : Weight Preserved (kg) :
Integrity :
Conservation History :
Laboratory Number :

Present Location

Present Location : Cyprus Museum (Lefkosia)
Private Collection :
Availability Status : On display
Disposition : Exhibition room
Room : 4 Stack :
Shelf : Case : A
Tray : Drawer :
Exhibition History :

Documentation

Administrative File Number(s) :
Published : yes
Photographs :

Bibliography :

Gjerstad, E. et al. 1935. The Swedish Cyprus Expedition. Finds and Results of the Excavations in Cyprus 1927-1931, vol. II. Stockholm: Swedish Cyprus Expedition, p. 697.

Documentation URL Address :

Recording Details

Initially Recorded by : Doria Nicolaou Date Recorded : 25-07-2013
Last Update by : Doria Nicolaou Date of Last Update : 27-08-2013

Figure 3.16
Digital description of a statuette conserved at the Cyprus Museum (kind concession of the DoA).

The different descriptions do not all follow information standardisation rules, preventing data interoperability among the host museums. Figure 3.16 shows the digital description adopted by the Cyprus Museum. The description of the items follows an 'in-house' tailored information organisation that satisfies the needs of the Department of Antiquities (DoA) researchers, but it is not built on any standard models (see Addendum). After permission, the digital archive is accessible only to the DoA personnel and external users.[157]

The descriptions adopted by the Medelhavsmuseet in its digital archive, named "Carlotta" (Figure 3.17), are structured according to an adaptation of two standards, the international CIDOC CRM[158] ontology and the Swedish standard SWETERM (see Addendum).

[157] See http://gis.da.mcw.gov.cy/cadip/

[158] CIDOC refers to the ICOM's International Committee for Documentation (http://network.icom.museum/cidoc/home/) and provides the museum community with good practices in museum documentation studies. In 1999 the CIDOC Documentation Standards Working Group – DSWG (http://network.icom.museum/cidoc/working-groups/crm-special-interest-group/) created the CIDOC CRM -Conceptual Reference Model (http://www.cidoc-crm.org/versions-of-the-cidoc-crm) an ISO standard (ISO 21127:2014) that provides definitions and a formal structure for describing the implicit and

As well as the Medelhavsmuseet, the digital archive of the Gustavianum is accessible and organised according to a descriptive metadata standard based on MODS and EAD, two schemas developed respectively for libraries and archives (see Addendum). The remaining museums hosting the Ayia Irini assemblage do not have publicly accessible digital archives for the material they host. Malmö Konstmuseum describes the items according to a few non-standard descriptive fields, which are accessible internally (Figure 3.18). LUHM is currently building its database; at the moment, the only descriptions are the one published by Gjerstad et al. 1935 and some information reported in old written notes.

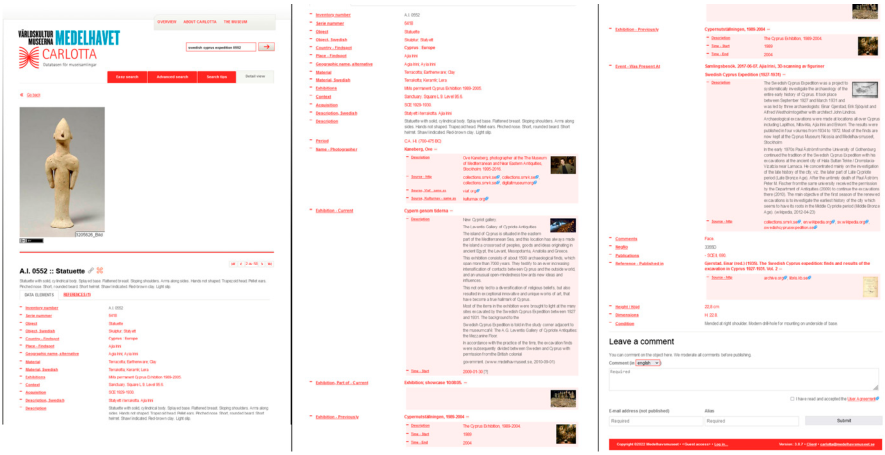


Figure 3.17
Example from “Carlotta”, the Medelhavsmuseet digital archive (public domain©).

explicit concepts and relationships used in cultural heritage documentation (Biasotti et al. 2016: 58). The semantic model provides several extensions that correspond to the specialisation of the ontology for various descriptive scopes: CRMarchaeo, for archaeological excavation data description; CRMdig, for digital provenance information; CRMgeo, for spatio-temporal information; CRMsci, for scientific observation model; CRMinf, an Argumentation model.

Malmö Konstmuseum
2017-10-24

Inventeringslista med bilder utan placering

Inventarie nr.	MM 25251
Konstnär	Okänd
Titel	Statyett
Årtal	600-450 f.Kr
Material / Teknik	lergods, gult,
Mått	Föremålets mått: 25,5 cm

Figure 3.18
Malmö Konstmuseum Ayia Irini artefacts' description (kind concession of the MK).

Overall, there are five key assessments of the museum collections:

- Not all the museums have a digital archive nor a structured description;
- Some archives follow non-standardised descriptions (e.g., a list of descriptive fields developed after internal needs);
- Some museums follow different standardised descriptions (with a preference for metadata);
- The variety (or the absence) of a standardised description prevents interoperability and a unified point of access for data retrieval and comparative research;
- They all refer only to the archaeological objects, and none provide information about their related content. For instance, there is no information regarding the digital provenance of the artefacts' digital images or the digitised excavation documents (the only one giving minimum information about these kinds of data is the Medelhavsmuseet).

The last point is particularly important not only for what concerns the current research but also for filling the gap in tracing the information regarding the already existing 2D documentation (e.g., digital images, 2D scans of texts and plans) carried out within the museums, and the 3D and analytical documentation (e.g., 3D models of artefacts) developed for the current research.[159]

[159] This is also important in the view of a growing trend towards the 3D documentation of museums' collections. Indeed, in the last few years, many museums and cultural

Semantic structures as a solution[160]

The variety assessed for the current research data underlines the need for a common and homogenised description (Ronzino et al. 2013). As mentioned, there are various and different descriptions in the museums' databases, so they might suffer from a problem of inconsistency (Jeong et al. 2005). Moreover, 3D digital resources needed a different structure than the one created by the museum. This inconsistency prevents common access to the whole information, also precluding data transparency. The solution to overcome such differences is adopting metadata standards and ontology to represent the semantics of this data, homogenise it, solve any data inconsistency problems (Stephens 2004), and guarantee common access to 2D and 3D data (Vassallo & Pitzalis 2012; Amico et al. 2013).[161]

Many metadata models exist in the Cultural Heritage field for data integration and interoperability: Dublin Core (DC)[162], the MARC standards family,[163] and LIDO[164] are some of the most used. Nevertheless, these standards are either too basic or too specialised. Moreover, none of them gives the possibility to document digital data provenance. Therefore, I decided to structure all data from museums' databases, literature and digital documentation according to the **STARC metadata schema** (Ronzino et al.

institutions are digitising their material, both in the form of 2D images and of 3D models. For instance, the 3D models of the sample studied in this research will be provided to the respective hosting institutions for the future implementation of their digital archives.

160 The topic of the semantic structures as a solution for data standardisation and integration is treated in Vassallo & Felicetti 2020 and partially presented in this section.

161 This solution is useful for the future development of a common digital archive to integrate the 3D digital datasets created for this research and guarantee the semantic interoperability of all the Ayia Irini data. This research part consists of preparing the necessary requirements to make this happen. Meanwhile, all data, raw and processed, and related metadata descriptions are stored in different repositories (CyI - CyTera cloud and Lund University cloud) for preservation purposes.

162 DC (http://dublincore.org/) is a metadata schema born to describe both physical and digital resources such as books and artworks.

163 MARC (https://www.loc.gov/marc/) metadata was created for the representation of bibliographic information.

164 LIDO (http://www.lido-schema.org/schema/v1.0/lido-v1.0-schema-listing.html) is a schema intended for delivering museums and CH objects metadata within digital libraries projects. For instance, Europeana supports the use of LIDO for aggregation to the EDM (Vassallo & Piccininno 2012). Although LIDO is CIDOC CRM compatible, it generalises the information not resulting semantically apt for detailed analysis (Biasotti et al. 2016: 69).

2012[165]; Ronzino et al. 2012; Vassallo et al. 2016: 93-94) to facilitate their organisation. Compared to other standards, the structure of this metadata scheme allows describing both the CH asset, its 2D/3D digital counterpart, recording all information regarding the digital provenance, paradata, activities and decisions taken during the production process (Figure 3.19). The scheme arises from integrating some of the most important metadata schemes developed within digital libraries European projects (Ronzino et al. 2011), such as LIDO and CARARE[166], and it is CIDOC CRM ontology compliant (Le Boeuf et al. 2012).

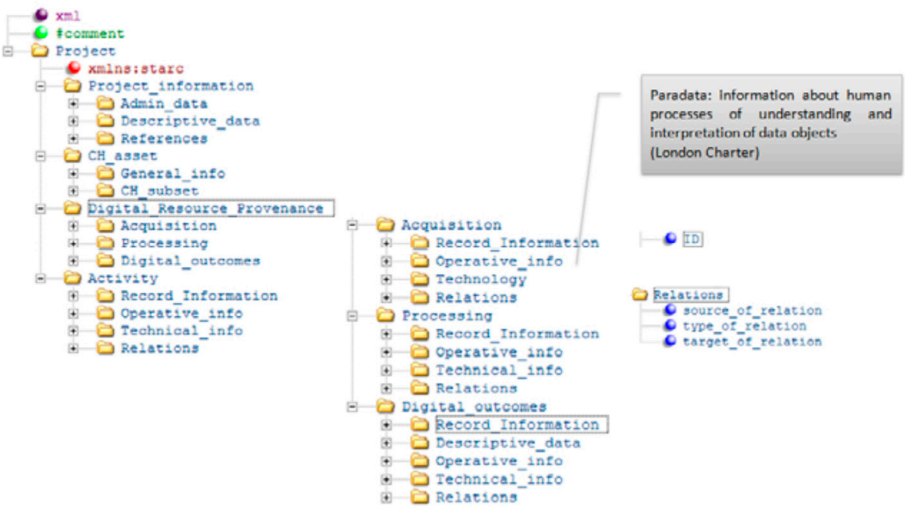


Figure 3.19
The STARC metadata schema (Vassallo et al. 2013).

Therefore, the Ayia Irini artefacts information has been structured and described according to the STARC metadata schema for making homogeneous the "unstructured" data, the semi-structured one from the museums' archives and also the 3D digital documentation. Moreover, multidisciplinary aspects (e.g., geometric, analytical) characterise the current

165 Experiments are carried out also on the development of STARC metadata schema extensions, such as the one created for the description of Cypriot digital inscriptions and epigraphies, the "CyInscription metadata schema" (Vassallo et al. 2013).

166 http://www.carare.eu/swe/Resources/CARARE-Documentation/CARAREmetadata-schema

study, but no particular structures could describe them properly. The STARC metadata schema was tested for implementation to integrate the part related to the scientific observation, the process and the results into the structure. Unfortunately, the development of the model for the scientific part was not accurate enough to describe the whole data. Consequently, I decided to review the available metadata standards used for scientific data, but that solution was not satisfactory in describing the multidisciplinarity of the whole Ayia Irini material.

It follows that different disciplines require different approaches, logical organisations and different ways of data documentation. Moreover, datasets produced by different disciplines can present many issues, such as fragmentation, data heterogeneity and inhomogeneity, and lack of standardisation. In such a variegated environment, it is necessary to establish a knowledge communication framework that can guarantee some basic principles, such as an inclusive description and documentation of all the interdisciplinary digital resources. The current research on Ayia Irini demonstrates such a variegated environment: the presence of data from different disciplines and the related approaches and differences need a common knowledge communication framework. For this reason, it was necessary to find a semantic solution to harmonise the various approaches and descriptions developed by the different disciplines and describe the relationships between data.

Generally, scholars prefer to use metadata models rather than ontologies. Nevertheless, metadata standards are inevitably limited to describing only a few specific aspects of the data content and are domain related. Therefore, a more flexible and less flattening solution is needed to capture the data semantics, the content/meaning and the relations.[167] The ontologies are the best solution for this scope: a set of concepts and relationships between those concepts represent knowledge. For this reason, core and domain ontologies are increasingly becoming the preferred tools to structure multidisciplinary data to solve the problem of data harmonisation and data integration.

Consequently, after assessing various ontological solutions (see Vassallo & Felicetti 2020: 5-7 for a review of the CH and related domains) and analysing the overall Ayia Irini data, it has opted for the use of CIDOC CRM ontology. The CIDOC CRM generally provides a semantic framework that integrates different data from different sources. Thus, it has been identified as the ideal knowledge communication framework to overcome the heterogeneity of the Ayia Irini information. This ontology is a versatile tool

[167] The problem is already treated by Madin et al. 2007 in the ecological field.

for modelling complex units and has recently been used in many data integration projects, avoiding the risk of information loss that usually afflicts transformation operations between formats. Several experiments tested the ontology's stability within different fields (also serving the need for cross-disciplinarity), and the possibility to develop it further proved its flexibility.[168] Indeed, thanks to its structure, CIDOC CRM allows the development of the core ontology and the several extensions created for the description of different fields. Such an updatable, enrichable, and extensible structure well supports an 'ongoing work' as the current one about the reassessment of an archaeological assemblage and its excavation, from which possible new data and interpretations might come up and need integration.

Therefore, within the current research context, an important role is played by interoperable schemes beyond the support of specific terminological tools.

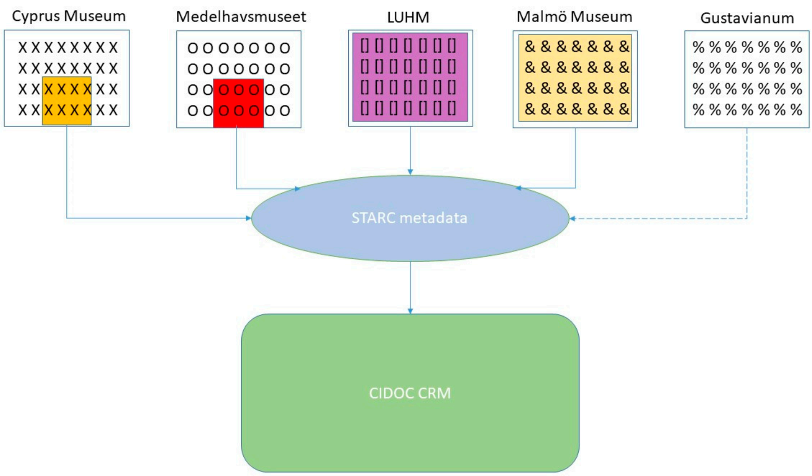


Figure 3.20
Schema of the semantic modelling pipeline (Vassallo©).

[168] CIDOC CRM provides a framework for data interoperability across archives, libraries and museums as well as different disciplinary areas respect to the Cultural Heritage. Ariadne (https://ariadne-infrastructure.eu/; Fernie et al. 2016), Parthenos (http://www.parthenos-project.eu) and Vi-SEEM (https://vi-seem.eu/) are some of the projects aimed at establishing cross- and inter-disciplinary research infrastructures using and testing this ontology.

The semantic modelling data process[169]

Hence, the ontology is to standardise and describe the various resources (real and digital) homogeneously. The described work represents a modelling solution intended to document multidisciplinary data, activities, and interpretations semantically, enabling cross- and inter-disciplinary interoperability with the overall documentation. The methodological pipeline developed for this research ends with the alignment of the concepts of the Ayia Irini data to the identified cross-disciplinary ontology (Figure 3.20) by semantically describing their relationships. The current research analysed data from different perspectives making explicit the entities (semantic concepts) and the properties (semantic relations existing between them). The data integration and standardisation methodology consists of the following steps (Vassallo et al. 2018: 115):

1. analysis of the whole data
2. Mapping the Ayia Irini data concepts to the entities of the CIDOC CRM ontology and its extensions is useful for describing it. Particularly, in this research, the extensions related to archaeology, digital provenance and scientific observation have been used (e.g., CRMarchaeo[170], CRMdig[171] and CRMsci[172]).
3. Review of existing entities and identification of missing concepts within the ontology needed for the case study description.
4. The overall integration of the entities and properties to cover all concepts related to the Ayia Irini case study data (archaeological, geometrical, analytical and digital).

These operations, conducted on multiple archives and multidisciplinary datasets, are usually difficult to integrate due to their different origins, nature

[169] This section of the thesis has been partially published in Vassallo et al. 2018.

[170] CRMarchaeo (http://cidoc-crm.org/crmarchaeo) extension allows describing all the events concerning the archaeological excavation, the context and the discovery.

[171] CRMdig (http://www.cidoc-crm.org/crmdig/fm_releases) is a compatible extension of CIDOC CRM to encode metadata about the steps and methods of production ("provenance") of digitization products and digital representations such as 2D and 3D created by various technologies.

[172] CRMsci (http://cidoc-crm.org/crmsci/) is a Scientific Observation Model, a formal ontology extension of the CIDOC CRM. It is intended to be used as a global schema for integrating metadata about scientific observation, measurements and processed data in descriptive and empirical sciences such as biodiversity, geology, geography, archaeology, and cultural heritage conservation in research IT environments and research data libraries.

and structure. They allow their effective fusion in one semantic graph and thus in one single archive, guaranteeing their full integration (Figure 3.21).

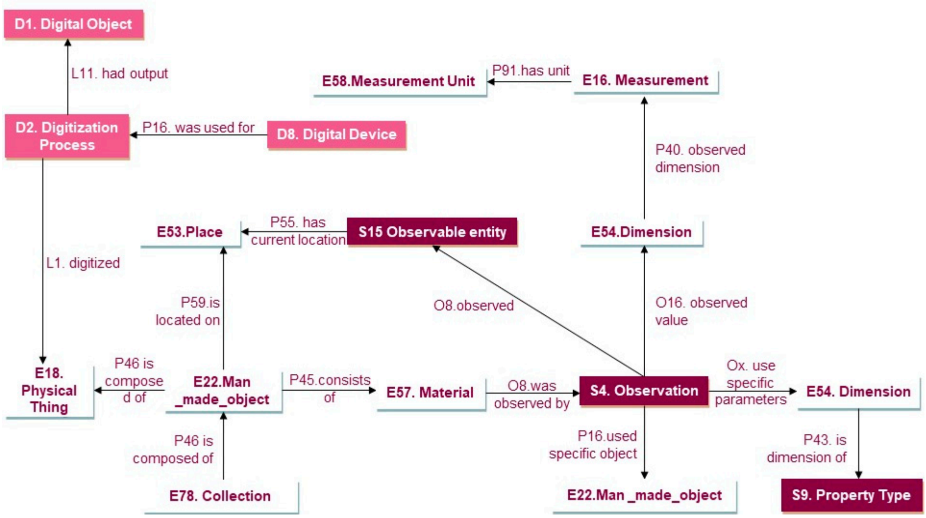


Figure 3.21
Mapping to CIDOC CRM and the integration of its different extensions (Vassallo©).

4. Digital Analysis, Study and Comparisons

The classification and interpretation of Ayia Irini's material derive from a traditional study method, based on the description and comparison through visual analysis and manual, linear measurements. This chapter addresses more specific questions that arose after analysing the collection and identifying issues and characteristics. And it does through a quantitative study, as addressed in the aims of this research.

Comparison is a fundamental activity in archaeology because it is the base of similarity assessment between artefacts for their interpretation. Similarity can cover any aspects of the objects, such as shape, geometry, texture, and material composition (e.g., pigments, clay). For coroplastic productions, we must investigate aspects of the *chaîne opératoire,* including:

- Methods: certain characteristics[173] help researchers identify specific conditions related to the production of artefacts, linking levels of expertise and, possibly, artisans.
- Signatures: similar elements such as fingerprints, unique shapes and features, and recurrence of identifiable elements (due to *connaissance* or *savoir faire*) determine if a collection is the work of one artist, a group, or a workshop.
- Materials: physico-chemical characteristics of clay and pigments allow the researcher to identify the materials and locate their provenance.

Before discussing the method of production, artisans' signature and level of expertise, it is important to consider that materials and techniques correlate to periods. Changes in materials and processes may show shifts in production.

[173] For instance, the thickness of the objects' clay, the direction and working of the material, the preparation sequences and assembly of the parts are useful information for the production identification of artefacts.

Archaeologists investigate those changes to understand the evolution of the productions; unfortunately, we cannot always explain what triggered the innovations and when.

Therefore, we also study expertise (or knowledge) levels to detect the difference between the manufacturing and the methods and if the artisan could obtain the planned results. Nevertheless, it could also be true that diverse levels might not reflect individuals' assessments, but they can more easily trace individuals' production. Following a methodology of artisanal interpretation that allows identifying an artisan's technical level or recognisable characteristics directly on the artefacts, we can infer their social contextualisation.

Dreyfus & Dreyfus (1986; 1990), and recently more synthetically Botwid (2016: 32-33), treat this approach in their phenomenology of skills acquisition and expertise development as "steps of acquiring skills" by an individual and reflection of the 'level of knowledge' on the artefact.

The artisanal analysis allows further information about the production and interpretative information. The signs of human actions (e.g., detection of tools, use of textiles or organic material) and hands (e.g., individual characteristics both in the production and decoration; fingerprints) contribute to the artisanal interpretation. Beyond giving hints about know-how and levels of expertise, all this information permits to find of specific features for further investigations (e.g., *chaîne opératoire*, specialisation in the production of the parts, adoption of rules for the fabrication -see Zapassky et al. 2006-, identification of hands/workshops).

Therefore, for such an artisanal identification, we should consider several features: the manufacturing technique, manufacturing level, shape, weight, size, method, material, decoration, and thickness. These features are critical parameters to interpret the artisanal signature of a workshop or even an individual (Dreyfus & Dreyfus 1986: 19-36, Dreyfus & Dreyfus 1990; Budden & Sofaer 2009: 10; Botwid 2016: 32-33).

Overall, archaeologists rely on visual approaches to compare the features to locate and explore similarities and differences to uncover information about patterns of production, levels of expertise, workshops, individual artists, and links between communities and periods.

4.1 3D geometrical analysis and comparisons of the small terracotta figurines

The fact that comparison is critical to the study of archaeological artefacts raises questions about the role of 3D geometrical analysis. How can 3D geometrical analysis identify production techniques and levels of expertise? How can 3D digital analysis find morphologic features and similarities to identify manufacturing and crafting signatures? How can 3D geometrical analysis investigate fixed measurements, rules, and ratios related to standardisation or specific workshops or artists? Can 3D geometrical analysis identify and group individual coroplasts or workshops?

The biggest problem in classifying archaeological artefacts, especially statuettes, is the difficulty of establishing well-defined metric variables. The SCE's Ayia Irini statuettes classification review shows the complexity of deciding objective criteria for clustering the artefacts into meaningful groups. This research proposes a 3D digital approach to analyse manufacturing details through their geometric properties. Several properties can represent the criteria for similarity assessment or attribution to a group (Biasotti et al. 2018: 104).

The following criteria are essential components that, when combined, allow for similarity assessment finalised to classification:

- Overall size: Overall space occupied by an object. Used with other criteria for comparison.
- Shape: Used for quantitative comparison of the form to group objects.
- Part size: Includes heads, arms, and bodies. Used alone or with other criteria for final comparisons.
- Thickness: Used with other criteria to ascertain dexterity level.
- Decoration: Includes type of decorations and details. Used to group objects according to the same technique.
- Colour: Includes clay, slip, and pigment. Used to group objects according to material composition and provenance.
- Material surface texture: Includes roughness of the material and surface appearance. Used to identify similarities between the production technique and hands.

Figure 4.1
3D Ayia Irini statuettes show the combination of variability (Vassallo©).

Chapter 3 reports on the application of 3D descriptors for geometric comparison and classification purposes in different fields. This dissertation uses 3D descriptors as quantitative support for classification and interpretation. Geometric and topological criteria provide significant quantitative descriptors to support the similarity search. Specifically, I applied computational geometric modelling methods to the Ayia Irini 3D digital statuettes to evaluate dimensions (Figure 4.1). I also ran a (semi)automatic non-supervised classification of the material to find results helpful to their archaeological interpretation. The application of these methods allows automatic and semi-automatic identification of features that we can compare to create similar clusters. Comparing the 3D models of the artefacts and their parts makes it possible to evaluate shapes and sizes.

The possibility to compare the geometry of the objects quantitatively can reveal new information in the manufacturing of the artefacts (e.g., technique, workshops, hands, patterns). The digital analysis of 3D shapes, together with an analytical and semantic investigation, is a valuable source of knowledge and can shed new light on the study of coroplastic to better understand production, provenance and dating to a broader extent.

According to current research, the quantitative analysis through 3D shape analysis can answer the archaeological research questions that the material of Ayia Irini raised. The current chapter will present the approach, the analysis, and the results.

Geometric and topological tools for quantitative analysis

The proposed 3D digital and analytical *chaîne opératoire* approach presents a geometric part fundamental for the artefacts' classification and interpretation (see Figure 3.1). The following (ideal) pipeline summarises the 3D shape analysis:

- Identification of the features
- Quantitative description through shape descriptors (= measurements)
- Use of the shape descriptors (geometric properties and algorithms)
- Comparison of the features represented by descriptors to identify similarities
- Similarities clustering
- Archaeological interpretation

In this pipeline, measuring the shape similarity between the objects is essential. We need to identify unique features and their related shape descriptors. To do so, we must decide which measurements relate to the research questions. Then we must choose a computational method to find and compare the measurements. We need to associate the shape of an object with a shape descriptor, which allows us to produce a similarity index by comparing those descriptors.

For this dissertation, we relied on already existing shape analysis descriptors and tools (see Chapter 3) and a combination of them for better performance. Table 4.1 summarises the measurements, geometric tools, topological systems, and methods used. The table also shows the algorithms partially implemented for this research and possible future implementations; the current chapter provides practical examples of the algorithms' applications and aims.

Table 4.1
Geometric and topological tools for the Ayia Irini 3D models analysis.

<table>
<tr><th colspan="2">Quality</th><th>Entity</th><th>Technique</th></tr>
<tr><td colspan="4">Algorithms implemented or partially implemented (base for future research)</td></tr>
<tr><td colspan="2">Thickness</td><td>Transversal slices</td><td>Slice the statuette’s base and calculate the average distance between the inner and outer edges.</td></tr>
<tr><td rowspan="2">Circularity</td><td>Eccentricity</td><td>Transversal slices</td><td>Extract the Minimum Bounding Rectangle (MBR) of the slice (following the approach described by Toussaint 1983) and then compute the ratio between the major and minor axis of the MBR.</td></tr>
<tr><td>Roundness</td><td>Transversal slices</td><td>Fit a circle (Coope 1993) to the slice and extract the distances between the point. Roundness of a slice measures similarities to a circle. Roundness is also an average error between the shape and a best-fit circle.</td></tr>
<tr><td colspan="2" rowspan="2">Straightness</td><td>Multiple transversal slices</td><td>Extract slices at different heights and compute the average of their barycentre. Then, calculate the distance between its barycentre and the average, which approximates the distance from the principal axis.</td></tr>
<tr><td>Transversal slices</td><td>Calculate the distance from the principal axis through:
1. The rotational symmetry axis.
2. The line passes through the centres of the bases of the best-fitting cylinder.</td></tr>
<tr><td colspan="2" rowspan="2">Size of the object</td><td rowspan="2">Volume</td><td>Calculate its bounding box.[174] Calculate the volume of the obtained parallelepiped (area of the base times the height).</td></tr>
<tr><td>Translate the triangular meshes into tetrahedral ones to approximate the volume.[175]</td></tr>
<tr><td colspan="2">Shape of the face/head</td><td>Multiple transversal slices</td><td>Extract transversal slices of the head and then compare them.[176]</td></tr>
</table>

[174] We obtained the Minimal Bounding Box using an exact algorithm (https://github.com/juj/MathGeoLib) of MathGeoLib (an online C library under Apache 2 license, http://clb.demon.fi/MathGeoLib/nightly/), that follows the approach described in Jylänki (2015).

[175] This technique to obtain the volume descriptor of a shape needs future development.

[176] At the moment, the comparison of the multiple transversal slices for the heads is qualitative. The method needs future development to obtain quantitative comparison.

Quality	Entity	Technique
	Multiple transversal slices	Extract a skeleton-based description of well-defined slices that enclose the principal characteristics of the head (e.g., the transversal slice passing through the tip of the nose).
	Local descriptors (key point based)	Search and extract local (keypoint-based) descriptors using key points and find correspondences.
Features position	Surface	Exploit surface information, for example, curvature and shape, to find the exact position of features such as arms, joints, and head peg.
Multiple measurements	Transversal slices	Extract from transversal slices measurements of figurine parts (e.g., total height, arms' length) for comparisons and standardisation analysis.

Shape analyses applied to statuettes' bodies

The statuettes sampled for this study present various characteristics concerning their production. Therefore, they are essential for identifying the best shape descriptors to distinguish, for instance, the technique employed, the presence of different hands, or expertise levels. We considered several measurements to quantify these characteristics: for example, the variance of the clay's thickness in the statuette's tubular body, the roundness (or circularity), and the eccentricity of the body. Archaeologists suppose that artisans produced the Ayia Irini hollowed figurines using the wheel. According to the technique and the artisan skill, the result will be a perfectly circular hole centred in the middle of the shape and a more or less uniform thickness of the walls.

Similarly, for handmade figurines, an experienced craftsman can produce by hand a more rounded, straight, and homogeneous body compared to a novice, but of course, with a different grade of roundness concerning a product created with the wheel. Likewise, in some cases, errors in any figurine's straightness and circularity can be due to inexperience.[177] From an

[177] Such an issue can be due to the novice's inexperience in either modelling the statuette or leaving to dry a statuette produced with too-wet clay, consequently subjected to deformation (pers. comm. with Prof. Athanasia Kanta). Concerning the production technique identification, even archaeologists have difficulties to discern whether a figurine was made by hand or with a mould. Within the discussion of the ICAANE 2021 workshop 'Standardising Creativity: Analytical tools for the study of clay figurines in the Mediterranean and Near East", where I presented my work, scholars agreed with the need for an approach to solving this kind of issue related to the recognition of the production techniques.

archaeological point of view, the precision of the measurements can represent different levels of expertise in creating a regular shape. Therefore, we can use such measurements as elements for automatically or semi-automatically clustering the artefacts.

The following geometric descriptors help quantify data related to technique and expertise (Figure 4.2):

- Roundness: Circularity of the tubular part of a statuette
- Eccentricity: Elongation of the body
- Thickness: Uniformity of clay coving the tubular portion of a statuette[178]
- Straightness: Distance from the principal axis

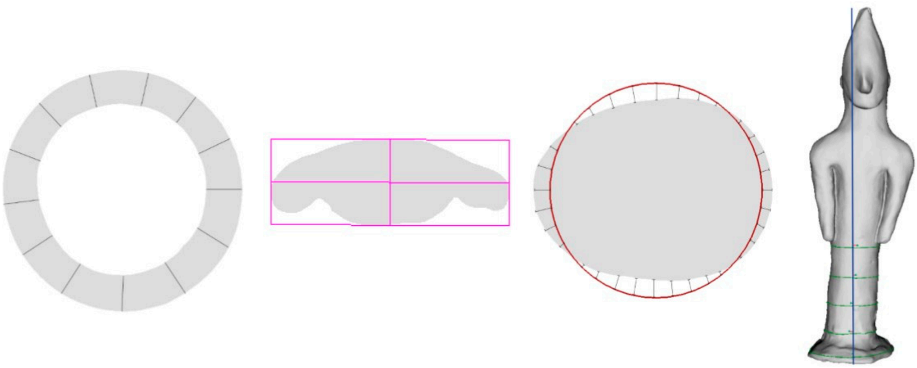


Figure 4.2
Thickness, Eccentricity, Roundness and Straightness respond to questions about production (Vassallo©).

To estimate dimensions, we virtually extracted slices at increasing heights from 3D models—these are the "slices" mentioned in Table 4.1. We can apply the transversal slices to the statuettes' bodies and heads.[179] In the current research, for what concerns the body slices' calculation, the analysis focuses on the lower part: we sliced the tubular portion at different predefined heights, and then we applied and evaluated the shape descriptors (e.g., to identify expertise levels in the production).

[178] It applies only to hollow, wheel-made statuettes.

[179] The slices considered are mainly horizontal, but for specific tests we also extracted some vertical ones (see shape analysis applied to the figurines' heads).

Roundness is computed slice by slice as the average distance between the shape and its equivalent circle (circle centred on the shape's centroid, which has the same area as the slice). Using circular regression, we can compute roundness differently, such as the best-fitted circle. Nevertheless, the equivalent circle is computationally lighter to compute and, since the slices are sufficiently round, is a good approximation of the fitted one. As shown in Figure 4.3, as the shape approaches that of a circle, the differences between fitted and equivalent become thinner.

We can apply eccentricity to any body type in the sample (e.g., hollowed and wheel-made, solid and handmade), measuring the shape's outermost contour. The eccentricity of a statuette's body determines how much one shape is elongated. It is obtained by computing the ratio between the maximal and minimal axis of the Minimum Bounding Rectangle (MBR) that encloses the polygon in each slice. We considered such a descriptor to train the clustering algorithm and automatically distinguish the statuettes according to their shape variations. For instance, statuettes presenting a different position of the arms[180] present a similar eccentricity—the algorithm groups them accordingly.

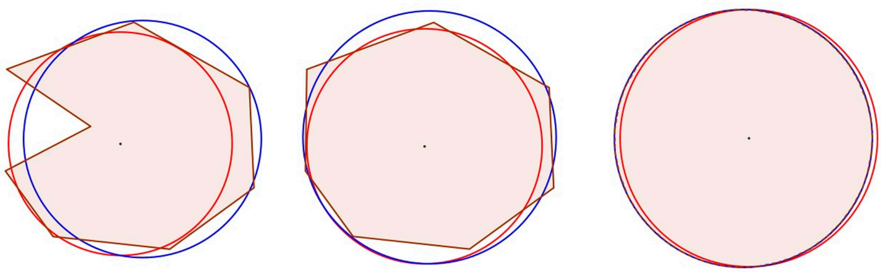


Figure 4.3
In this experiment, we computed the difference between the fitted circle (blue) and the equivalent circle (red) from the original shape (brown) (Vassallo©).

Thickness applies well to hollowed or fragmented statuettes with an inner cavity that the 3D scanner only partially captured. However, detecting the recess in the lower slices as an inner planar hole is possible. In this case, we analysed a set of slices of the shape, extracted by virtually slicing the model

[180] The presence of different attributes, such as small animals, vases and musical instruments, determine different arms' positions.

with parallel, horizontal planes at increasing heights. A good estimation is obtained by slicing the tubular part at different predefined heights and computing thickness for each slice. Therefore, the thickness is the average distance between each slice's inner and outer boundary. Successively, the thickness variance results from the extraction over the set of those slices.

Lastly, straightness depends on the definition of the axis, for which we set a linear regression system to interpolate the slices' barycentre. Unfortunately, this is sensitive to imperfections, resulting in a tilted line. An alternative approach focuses on the extraction of the axis of rotational symmetry. In this case, the presence of additional features applied to the tubular bodies (arms, animals, musical instruments, or other attributes and objects) can affect its precise computation. Therefore, we decided to focus on the tubular, symmetrical portion, where it is easier to locate the axis. Specifically, we chose a vertical line passing through the barycentre's average. Thus, the straightness measurement is the average distance between the principal axis and the slices' barycentre.

Figure 4.4
Example of different elements on which we applied automatic recognition of the manufacture through quantitative descriptors (Vassallo©).

Automatic methods to detect regions for the application of descriptors simplify the analysis. For instance, automatically finding the tubular portion of the body or the head allows the research to indicate whether the parts were handmade or moulded; or automatically detect the arms to understand if they were made by the same artisan (Figure 4.4).

We conducted a "segmentation experiment" based on the paradigm of slices to segment the statuettes into meaningful subparts and successively use clustering methods to cluster similar ones (Figure 4.5). We extracted slices from the statuettes' entire height. To this end, we created a set of descriptors to apply to the statuettes' slices to cluster them into compatible parts. In several cases, a single class of shape descriptors might not be sufficient and satisfactory to characterise shapes. In contrast, different descriptors can highlight various features (Biasotti et al. 2016b:19). Therefore, the solution is to use multiple descriptors' categories to obtain all pertinent information and merge them into a common descriptor composed of all of them.[181] Integrating different shape descriptors can better find similarities in production and shape. Moreover, shape descriptors may automatize meshes comparison and identify similarities useful to interpretation. Of course, using a more extensive range of shape descriptors might result in a higher computational cost (especially processing time for retrieval purposes). Still, we can reach better results and improve classification accuracy and performance in general.

We applied the following set of descriptors to slices extracted from each statuette's entire height:

- <u>Elongation</u>: $1-\frac{m}{M}$, where m and M are the minor and major axis of the MBR (Minimal Bounding Rectangle - the smallest oriented rectangle containing the shape);
- <u>Solidity</u>: $\frac{A}{A_{CH}}$, where A is the area, and A_{CH} is the area of its *convex hull*;
- <u>Compactness</u>: $\frac{4\cdot\pi\cdot A}{P^2}$, where A is the area and P its perimeter;
- <u>Circular variance</u>: error concerning the equivalent circle;
- <u>Rectangular variance</u>: error concerning the MBR;
- <u>Euler number</u>: connected components - holes;
- <u>Hole-area ratio</u>: $\frac{A}{A_H}$, where A_H is the total area of all the holes.

To better understand the overall categorisation of the material, we applied a clustering technique obtained through a *k-means* approach (MacQueen 1967). Figure 4.5 shows the outcome achieved by clustering the slices into meaningful parts. In particular, the image shows the number of slice groups (3, 4, and 5) obtained on the statuette A.I.130, varying the k value

[181] In merging different descriptors, the shape properties to choose from can represent several geometrical analyses of the objects under study, from curvature to height, from circularity to other extra geometric information, such as texture and decorative patterns. This kind of approach is also known as the multi-modal description: we can apply it to an object as a whole and its different parts (Biasotti et al. 2016b: 19, 21). As for an example, the approach proposed by Biasotti et al. 2014a and Biasotti et al. 2015a to assess the similarity between 3D artefacts applies on the multi-modal description for each 3D item considering several geometric attributes, together with colourimetric information.

respectively (k=3, k=4, and k=5). In the first result, colours reveal clusters and highlight similarities of parts. Indeed, this approach can help automatically distinguish and subdivide the constituent parts of the human figurines in terms of shape similarity. Subsequently, the areas can be automatically recognised and associated with a specific further descriptor for their quantitative analysis, comparison with other statuettes' parts and, consequently, global automatic classification of the assemblage. However, even if the integrated descriptors recognised specific areas, producing the correct number of clusters (k) is still challenging. This complication is ripe for future research.

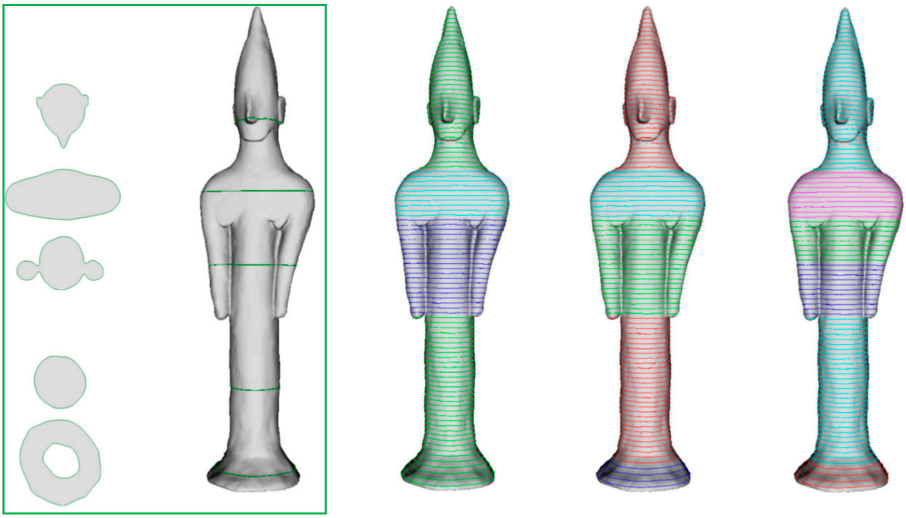


Figure 4.5
Slice clustering. On the left (within the green box) is the statuette A.I.130 with transversal slices highlighted; on the right, resulting k=3, k=4, and k=5 clusters. Disregard the same colours among the three representations of A.I.103 (Vassallo©).

The various areas automatically created by the multiple transversal lines need a check-control for their recognition and meaning. The subdivision into areas is easier for common and simple shapes (i.e., figurines with arms along the body). As visible in Figure 4.5, at least for the two tests run with the values k=3 and k=4, the arms' areas coincide, and the analysis defines and discerns them from other body parts. However, by increasing the k value (e.g., k=5), the slices' sets are more sensitive to variations. Consequently, the analysis divides those areas into smaller clusters creating further subgroups within the same feature that may or may not be significant. The situation becomes more complicated in the presence of more elaborate figurines, such as those bearing attributes.

On the one hand, the variance of the different cases helps cluster the features according to similarity; on the other hand, sensitivity to variations may create multiple clusters of slices that may or may not be significant. At this point in the process, the generation of sub-group slices requires continuous human control regarding the significance and applicability of the descriptors. Moreover, it compromises the test's primary scope of the process's automatization. These promising results support further study of automatic classification of the parts

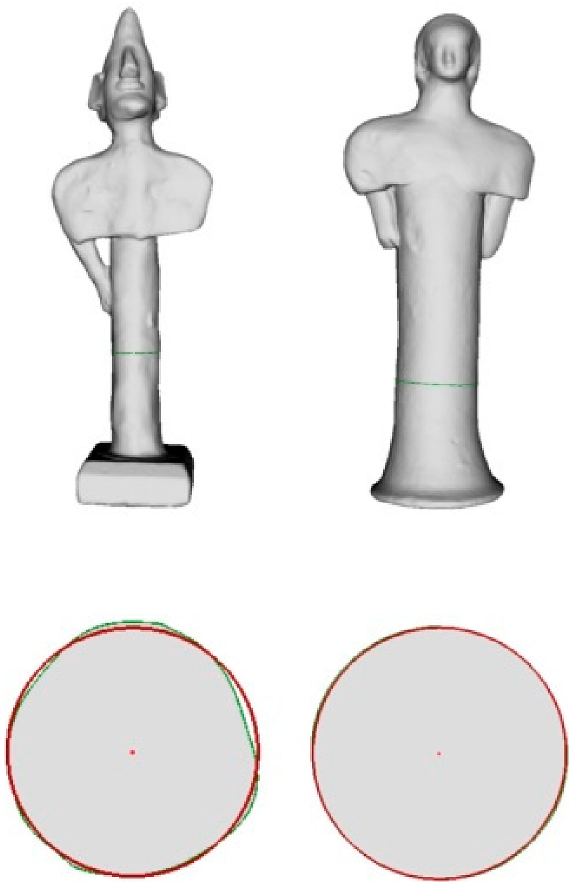


Figure 4.6
Best-fitting circle (roundness test) on a slice of the tubular part of two figurines (Vassallo©).

We ran a second experiment ("classification experiment"), which aimed to automate artefacts according to their production technique, differentiating between hand- and wheel-made figures. Gjerstad et al. (1935) already described the statuettes underlining these characteristics. However, to the current research aim, such classification is methodologically helpful to train the algorithm to automatically launch the proper descriptors depending on the case and give further or more elaborated clustering analyses. Specifically, we ran the statuettes classification experiment comparing the performance of Roundness and Eccentricity.

We applied the descriptors to the lower body of the sampled statuettes (Figure 4.6). The ideal would be to select slices automatically, but we would need to segment them into meaningful parts. For this reason, we applied the slice paradigm only on the lowest part of the bodies since the automatic clustering identified those areas well. Then the successive human evaluation confirmed its significance and descriptors' applicability. Therefore, at this research stage, we applied the two descriptors on 100 slices from the lowest part of each statuette (about 2/5 of the statuette's total height). Then, we calculated the average and the variance. We used this procedure to discriminate wheel-made statuettes from handmade ones, expecting the variance for wheel-made ones to be lower. Specifically, we established a threshold (= 0.030): all those figurines <0.030 are automatically attributed to the wheel-made group and those >0.030 to the handmade one.

Roundness calculations found 43 wheel-made and 60 handmade statuettes, while eccentricity calculations found 35 wheel-made and 68 handmade artefacts (Figure 4.7).

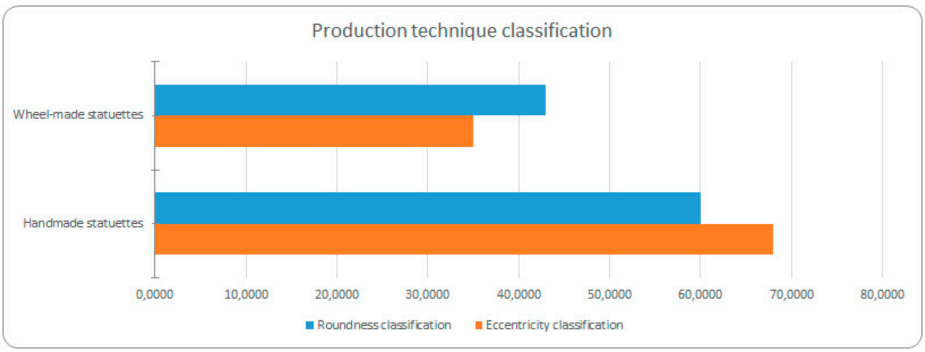


Figure 4.7
Production technique classification based on Roundness and Eccentricity descriptors (Vassallo©).

Consequently, we compared the classification scores in figurines attributed to the two production technique groups by the quantitative analysis with those operated by the SCE archaeologists' classification (Table 4.2). The Roundness calculation matches the SCE manual attribution exactly.

On the other hand, the Eccentricity calculation presents a slight difference between the two classification methods: the automatic geometric analysis, concerning the archaeologists' classification, attributes a further eight (8) figurines to the handmade technique concerning the wheel-made one. Eccentricity is obtained by computing the ratio between the maximal and minimal axis of the Minimum Bounding Rectangle (MBR) that encloses the polygon in each slice. Inclinations and changes of the axis due to small inhomogeneity of the shape might cause differences in the result.

Such a comparison is also essential to check the difference between the two methods and evaluate the descriptors used. For this reason, we performed the descriptors' accuracy analysis (standard measurements of the classifier's quality). Table 4.3 shows the accuracy of each measurement, taking into consideration Precision (fraction of relevant instances among retrieved instances), Recall (fraction of relevant instances retrieved over the total amount of relevant instances) and F1 score (measurement of accuracy related to precision and recall). Comparing the results of the "classification experiment" with those produced by the SCE archaeologists' manual classification, the clustering based on Roundness reaches the value of 0.8167, and Eccentricity achieves an F1-score of 0.6993, both with some manual tuning. The test shows that accuracy is higher with the Roundness calculation than with the Eccentricity calculation.

Table 4.2
Comparison of Roundness and Eccentricity with the SCE.

	Roundness classification	Eccentricity classification	SCE classification
Wheel-made statuettes	43	35	43
Handmade statuettes	60	68	60

$$Precision = \frac{|true\ positives|}{|true\ positives| + |false\ positives|}$$

$$Recall = \frac{|true\ positivives|}{|true\ positives| + |false\ negatives|}$$

$$F1 - score = 2 * \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

Table 4.3
Accuracy result for each measurement of the test (standard measurements about the quality of the classifier).

	Roundness	Eccentricity
Precision	0.8167	0.7353
Recall	0.8167	0.6667
F1 score	0.8167	0.6993

As before, some descriptors are more efficient than others.[182] Moreover, some descriptors work better with some shapes than others. For instance, we can measure thickness of the clay on a fragmented or hollow object but not on solid elements, and uniformity indicates a higher technical level of expertise. It can even point to the use of common tools or moulds and the production by the same or different artisans (Catalano et al. 2020: 367). In this research, we studied thickness of hollow objects in the sample, specifically on the automatically identified tubular part of their bodies. Consequently, we made ten slices to the tubular cavity to accurately calculate the thickness of its walls. For a discourse of uniformity, it was also necessary to control the slices' thickness. Using those regular intervals extracted for the automatic segmentation into parts of the shapes guarantees this uniformity: each slice thickness is equivalent to 1/100. After extracting ten slices, we compared their external and internal perimeter to obtain the thickness by calculating the average of the closest distances. More precisely, for each vertex of the interior perimeter, we calculated the closest vertex on the external one.[183]

The computation shows the clay thickness of the figurines with a variation averaging between 0.4 and 0.7 cm. In practice, we measure thickness starting at the top and moving to the bottom – thickness#1 corresponds to the highest, and Thickness#10 corresponds to the lowest slice. Figure 4.8 shows that slices at the top and bottom differ significantly from those at the centre. The difference between the internal and external perimeter is particularly high in Thickness#1 because the scanner struggled to acquire the inner measurement

[182] Moreover, some descriptors work better with some shapes than others.

[183] Currently, this is the best method possible, and it is already considered that if there are considerable distortions, the Thickness might not be the best distance to be calculated.

due to the diminishing cavity space.[184] Similarly, the increase of the thickness value at the bases is due to flaring, damage to the artefact, or lower workmanship level. The anomalies visible in the graph, such as the two pink lines with the final tale on 0 value (A.I.888 and A.I.92) and the light blue tale on the value 0.9 cm (A.I.1660), are due to post-production damages. Still, these do not invalidate the calculation of the average clay thicknesses on the rest of the bodies. We could not document the inner parts of some figurines due to limitations of the scanner in digitally acquiring the small space; these difficulties are represented by the high values on the left of the graph around Thickness #1 and #2. Similarly, some slices, usually Thickness#9 and #10, extended beyond the base, producing very high values, like the case of the black curve in the graph at around value 12= 1.2 cm (figurine A.I.584).

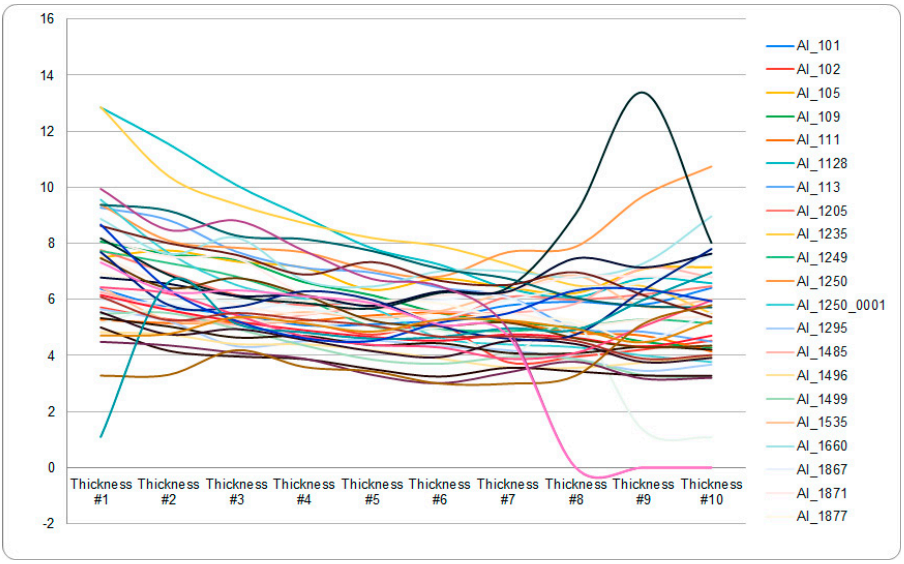


Figure 4.8
Analysis of the clay homogeneity through Thickness computation.[185] The negative values on the graph represent the damaged or broken areas of the figurines' bodies (Vassallo©).

[184] Other solutions, such as the use of micro-CT scans (Computed Tomography), might be helpful to acquire the inner of the figurines better. Unfortunately, the non-portability of these kinds of instruments and the museums' restrictions on bringing several artefacts for the analysis outside their premises made such a choice impossible.

[185] The legend on the right with the colours and IDs of the figurines reports only some of them due to space and visualisation issues. The graphic includes all the analysed statuettes.

Moreover, because of the efficient results obtained earlier, we also tested the Roundness descriptor to identify other characteristics beneficial to further group the artefacts according to the level of expertise. Specifically, we used the previously mentioned threshold (= 0.030), operated to identify wheel-made objects (< 0.030) and handmade production (> 0.030), to automatically identify issues or higher precision. We then associated these to a hypothetical experience level and sub-group the artefacts accordingly. Thus, the items in the wheel-made group presenting higher threshold values indicate the presence of some inaccuracies in the structure. Oppositely, a lower threshold value captures those with higher structure precision within the handmade group (Figure 4.9). The analysis automatically identified in the wheel-made group the figurines with structural issues. Nevertheless, it is impossible to automatically determine the nature of the imprecisions, and the descriptor needs future improvements for this specific purpose on a technical level. Concerning the figurines included in the handmade group, the descriptor highlights those characterised by more precise manufacture.

ID	Roundness	ID	Roundness
A.I. 101	0.0137	A.I. 37	0.0043
A.I. 102	0.0029	A.I. 393	0.0083
A.I. 105	0.0171	A.I. 405	0.0476
A.I. 109	0.0542	A.I. 412	0.0790
A.I. 111	0.0026	A.I. 448	0.0616
A.I. 1128	0.0076	A.I. 470	0.0556
A.I. 113	0.0197	A.I. 552	0.0630
A.I. 1205	0.0205	A.I. 842	0.0717
A.I. 1235	0.0466	A.I. 1547	0.0096
A.I. 1249	0.0058	A.I. 1548	0.0066
A.I. 1250_0001	0.0373	A.I. 649	0.0065
A.I. 1250	0.0184	A.I. 1299	0.0111
A.I. 1295	0.0033	A.I. 1916	0.0738
A.I. 1485	0.0215	A.I. 771	0.0107
A.I. 1496	0.0052	A.I. 1587	0.0080
A.I. 1499	0.0041	A.I. 1223	0.0071
A.I. 1535	0.0514	A.I. 608	0.0676
A.I. 1660	0.0454	A.I. 60	0.0054
A.I. 1867	0.0032	A.I. 710	0.0755
A.I. 1871	0.0344	A.I. 723	0.0696
A.I. 1877	0.0040	A.I. 740	0.1011
A.I. 245	0.0028	A.I. 741	0.0504
A.I. 3893	0.0298	A.I. 759	0.0557
A.I. 445	0.0263	A.I. 760	0.1220
A.I. 1507	0.2207	A.I. 816	0.0062

Figure 4.9
Example of Roundness values: they identify figurines with inaccuracies within the wheel-made group (left) and higher precision figurines within the handmade one (right) (Vassallo©).

Similar to the previous descriptors, we used Straightness (and symmetry) to identify groups of artefacts according to the artisans' levels of expertise. This descriptor applies to all the figurines included in the current sample since their tubular bodies allow for the extraction of the axis, a vertical line passing through the barycentre's average. Thus, I positioned the figurines' 3D models on the *xyz* space and projected them on a gridded background through the MeshLab visualisation and analysis tool (Figure 4.10). The *y* axial direction and the exact position of the figurine projection on the measurable grid allow us to calculate straightness and symmetry and lucubrating on the production level to identify expertise groups. We might consider the Straightness (and symmetry) measurement less meaningful for objects produced with the wheel since it produces straighter products. Nevertheless, this is not a predictable conclusion because the maker's ability influences the final result. On the other hand, applying this kind of measurement to handmade statuettes might provide more information about the experience level. Indeed, the lack of instruments shows the maker's dexterity.

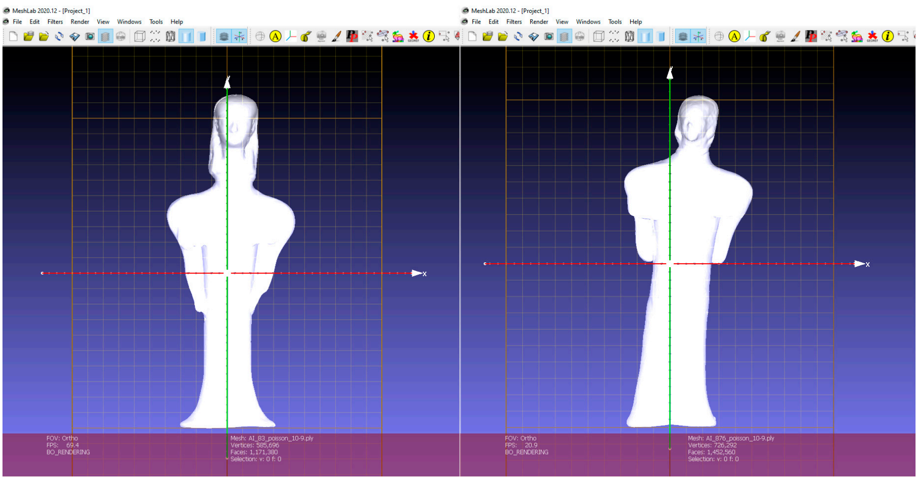


Figure 4.10
Straightness and symmetry calculation of some 3D figurines (e.g., A.I.83 on the left and A.I.876 on the right) (Vassallo©).

A classification descriptor can help divide the artefacts into sub-groups, understand their meaning, and conduct further analyses. In this vein, I conducted successive experiments on the entire body of the two sub-groups to obtain other significant patterns. We can use quantitative comparisons to learn if elements signal a workshop, specific individuals, experience levels or the use of standards and rules in the statuettes production. Before answering this question, we must define the entities and decide where and how to take measurements[186].

I established the following:

a) Total *body size;*
b) *Position* (and *shape*) and *length* of the arms;
c) *Base diameter*;
d) *Head height*;
e) *Weight* (clay amount);
f) *Ratio* between the body parts.

In this research, we considered the object's overall volume as an indicator for calculating the total body size (a). We obtained this measurement by computing the volume of the object's Oriented Bounding Box (OBB – the smallest box that contains the object). We also tried to use such measurements to calculate the amount of clay (e). However, that is a rough estimation, especially for the Ayia Irini hollowed statuettes, since the scanner struggles to acquire the entire cavity.[187] For the current research, we measured the weight (e) using digital scales.

We measured the height of the head (d) to calculate the ratio among the parts, including the neck/peg. We employed further descriptors for more precise measurement and analysis of the heads (see below in this chapter).

Concerning the arm position and length (b) and the ratio between measurements of body parts (f), we carefully studied the precise location of the junction between the body parts (e.g., arms and chest, head and trunk) as this could easily skew our measurements. Scholars agree that artisans crafted the bodies, heads, arms, and attributes separately and later assembled statuettes. Unfortunately, the outer clay rendering obscures most joints, which is essential to identify the figurines' parts and run geometric comparisons. Digital analysis helps since we can use measurements and geometric comparisons to find ratios and standards in the production.

In this chapter, I mentioned several criteria as elements on which we can perform similarity assessment experiments. Material surface texture can provide information about the artefacts' production and manufacturing. For

[186] A question in this regard is: where does an arm begin and end?

[187] For future research, we could render the object as a tetrahedral mesh, compute the volume of each cell, and then sum the volumes to calculate the volume of the whole, considering also the partial lack of the object's internal digital representation.

example, on the one hand, the roughness of the material hints at similarities in production: same signs, anomalies, faults, and patterns may indicate the use of a specific mould, instrument, or hand, thus reflecting the same or different artisans. On the other hand, the surface roughness enhancement helps detect features not visible to the naked eye that we can re-examine for further geometric and shape analyses. To this aim, it is possible to enhance roughness using curvature, which locally characterises bumps and hollows on a surface. In 3D shape analysis, curvature-based methods rely on the assumption that most points on a 3D shape are on areas with minor curvatures. Therefore, most points with low curvature are redundant; points with high curvature are unique and provide information about the shape. Figure 4.11 shows some of the curvature analyses we can compute on 3D shapes to measure their uniqueness (Laga et al. 2019: 97).

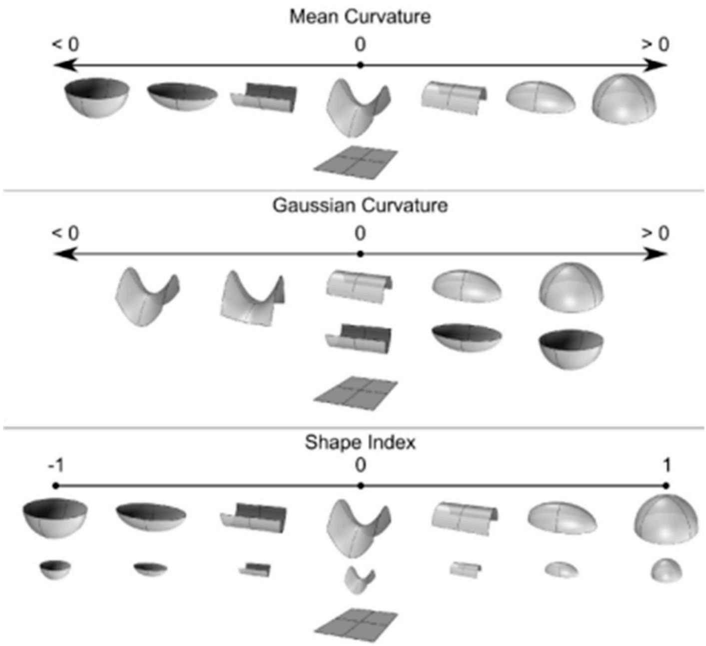


Figure 4.11
Some curvature indices computed on 3D shapes, e.g., Mean Curvature, Gaussian Curvature, and Shape Index (image adapted from Tsagkrasoulis et al. 2017:15, no. 5).

For this reason, the proposed methodology also considers these measurements. Beyond the basic measurements, we can usually perform on a digital artefact and the shape descriptors previously cited, we applied the above-mentioned geometric properties onto meshes.[188] Specifically, we applied the Mean Curvature and the Shape Index (Koenderink & van Doorn 1992) to the Ayia Irini 3D models to enhance the surface quality and detect useful features. This method highlights the convex or concave nature of the object's surface and its roughness.[189] Figure 4.12 shows how the different colours of the Mean Curvature visualisation on the mesh surface help us to detect the curvature of the surface and obtain insights on its technical production and assemblage (e.g., wheel's signs, head and arms attachment area).

In the last decade, computer scientists developed several approaches to enhance the 3D characteristics of archaeological 3D models visually. For the case study, we used MeshViewer[190] to perform such 3D visual operations. The application provided efficient and targeted support in detecting edges, patterns, and working surfaces.[191]

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188 These geometric properties are pre-computed according to specific parameters already known in computer graphics – e.g., in Matlab).

189 Depending on the descriptor, different surface characteristics can be highlighted. For instance, the Mean Curvature well distinguishes areas of high and low curvature, convex and concave shapes. Shape Index is instead scale-independent and can discriminate clear shape characteristics (e.g., ridges, domes), despite their high or low curvedness (Tsagkrasoulis et al. 2017:15, no. 5).

190 IMATI-CNR developed the application within the GRAVITATE project to analyse archaeological fragments' curvature and to re-unify fragmented pieces (Catalano et al. 2017: 154, 157). MeshLab is also widely used by researchers to automatically enhance and analyse some characteristics of the 3D models, such as the curvatures of the surface. One of its most used rendering plugins (or shaders) is, for example, the Radiance Scaling (Vergne et al. 2010), which enhances the 3D model concavities and convexities. We used these MeshLab shaders for various analyses also within this research.

191 This analysis resulted in being limited to the aim of a micro-surface investigation. The type of 3D digital technique employed and available at the time produced high-definition models for geometric analysis. A structured light 3D scanner would have produced higher definition models also employable for micro-surface analysis.

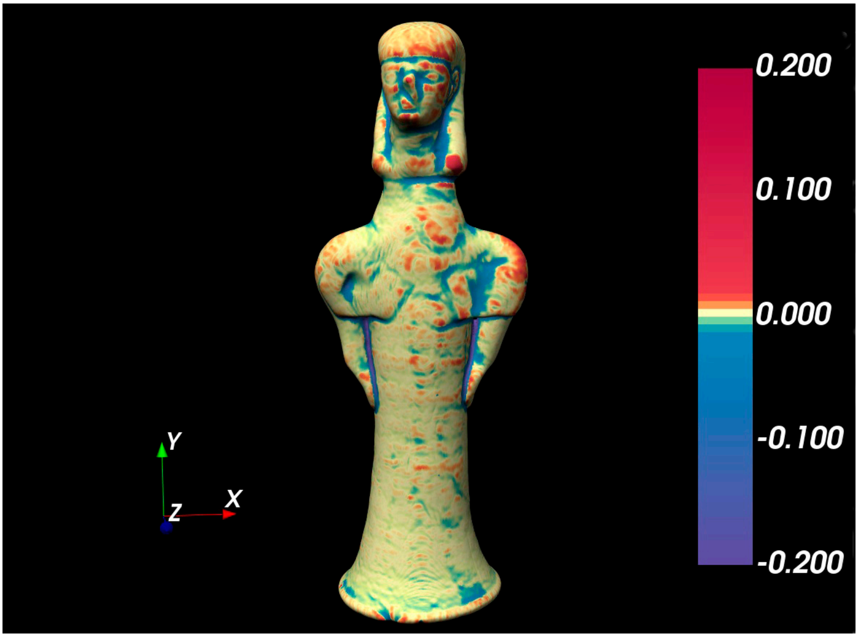

Figure 4.12
Mean Curvature calculated on the mesh surface: the point-wise curvature showed onto the mesh of the statuette A.I.85, following the colour bar on the right (Vassallo©).

Before applying the Mean Curvature and the Shape Index, we performed a specific operation on the 3D meshes with another application, GraviFix. Such a tool performs two functions in sequence automatically: 1. cleaning the mesh from any problems that could hamper further geometric analysis; 2. simplifying the models up to three size levels (and different resolutions) according to the specific geometric analysis, detail, or performance/speed of the performance needed (Mortara et al. 2017).[192] We proceeded to simplify and better manage the 3D models in MeshViewer since they had already been processed with MeshLab and ReMesh. The procedure does not affect the quality of the model for detecting features.

[192] GraviFix is another software tool developed by CNR-IMATI that fixes and simplifies meshes at three levels of detail: 1M, 100K, and 50K vertices. The operator can launch the process, compiled for Linux, through the command line and without a graphical interface. A script can efficiently operate on a set of files automatically. See also http://meshrepair.org/ for other mesh repair software.

The application successfully extracted geometric properties using .txt files containing numeric values[193] to calculate the two kinds of curvatures. Then, we loaded them with the Ayia Irini 3D meshes in the MeshViewer to visualise the results on the front-end (Figure 4.13). We did this for every object in the sample, extracting information about joints and junctions or any other sign attributable to the production.

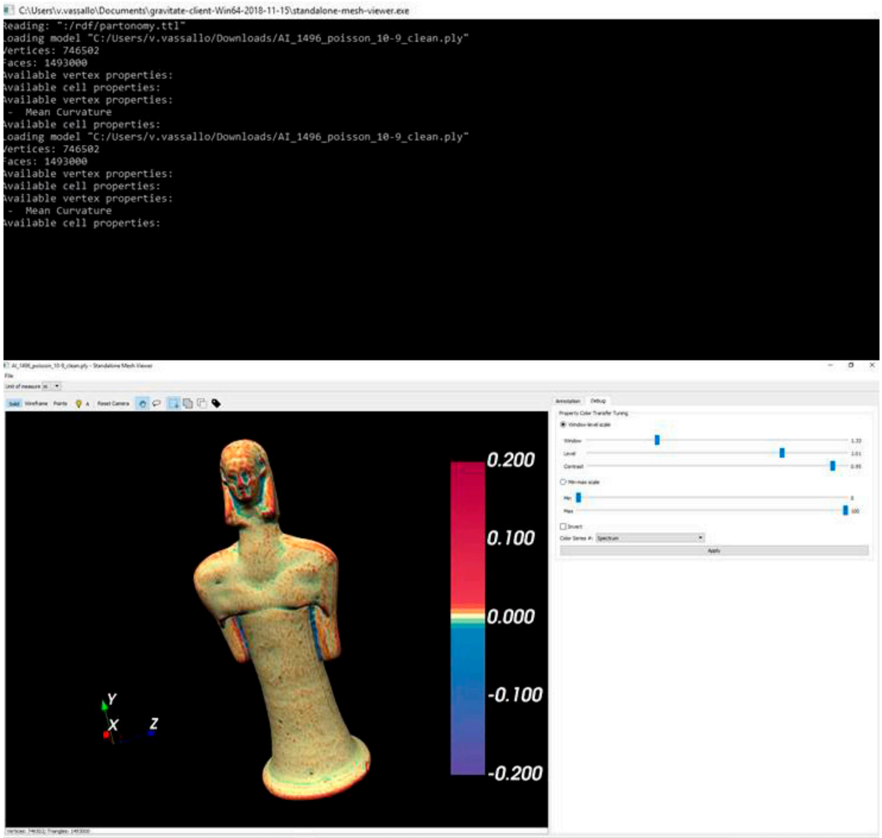

Figure 4.13
Curvature analysis carried out in MeshViewer (back-end and front-end view) (Vassallo©).

[193] The 'curvature.txt' contains one column that is a vector of scalar values, a value for each mesh vertex *v* that represents the value of the mean curvature in *v*. The'shape_index.txt' contains one column that is a vector of scalar values, a value for each mesh vertex *v* that represents the value of the shape index in *v*.

As mentioned in Chapter 3, I performed photogrammetric documentation to create textured 3D models of the objects, which I integrated with the geometrical models obtained from the laser scanner. However, tests on the digital statuettes, carried out separately to evaluate possible differences, revealed that the 3D models produced with the laser scanner technique and those created with the photogrammetric one give specific results according to the algorithm applied. For this reason, I applied the Mean Curvature and the Shape Index to all 206 3D models.[194] For instance, the photogrammetric 3D models show surface roughness variations better. It pointed out all the parts that correspond to the addition of clay in parts of the statuettes. In this way, we discerned the attachment of several elements (e.g., the appendage of the arms and the head to the body).

For some statuettes, the Mean Curvature calculated on their mesh better highlights even tiny reliefs of clay marking the joint's location or the addition of lumps of clay to cover the joined parts. Figure 4.14 shows how the blue lines outlined by the Mean Curvature on the statuette A.I.1496, representing the lower curvature (concavity), give exact information about the attachment of the parts. The analysis shows hidden elements in the inner area, on the statuette front, the position and exact extent of the head's tenon, and on the rear, as well as the attachment and length of the arms (in terms of clay extension). On the other hand, curvature tests applied to the 3D models produced with the laser scanner technique better highlight working and production signs. For instance, the analysis delineates the wheel's processing direction and the distances between the revolutions on the wheel-made statuette's body.[195] Such patterns are interesting because they highlight the objects' production process and level of expertise.

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[194] The amount of 206 items corresponds to the sum of the 103 3D models obtained by laser scanner technique and the 103 digital replicas produced with photogrammetric technique.

[195] The digital measurement of the spins' traces is at a distance between 0.4/0.5 cm up to a maximum of 0.6 cm. Especially when the spin's distance values are larger than the average measure, it is possible to observe an inaccuracy in the figurine's Roundness. For instance, the figurine A.I.876 has substantial values on the last revolution of the wheel, with a non-accurate shape result.

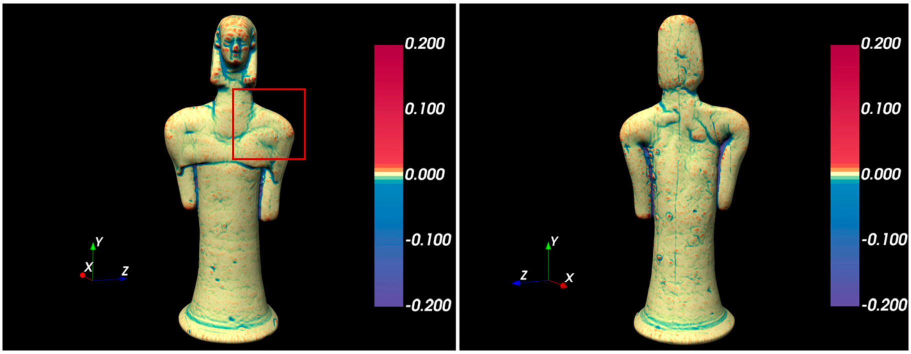

Figure 4.14
Curvatures results in the MeshViewer client (front-end). The software helped to identify all the joints of the attached elements (Vassallo©).

Measurement extraction

To identify all the statuettes' junctures and components, I evaluated all the curvature tests' results on the 3D models. The successive passage included the extraction of those components' measurements considered to be of potential significance to understand their range of variability and compare them to identify specific ratios as a possible expression of standardised production (Figure 4.15). The measurements are defined as follows:

- Total height (H). This measurement evaluates the existence of a standard measurement regarding height. Although the artisans created the statuettes by assembling various pieces, it is interesting to know if the total height remains constant and if it remains consistent within subgroups with some similarities (e.g., heads, decoration).

- Base diameter (BD). The Euclidean distance between the two points on the base, which are farthest from each other, is taken. Similar to the previous case, we measured this to understand if it remains constant in absolute terms and respects the other measurements. This measurement is to identify specific hands, check the artisan's skill, understand if he/she always repeats the same dimension, and evaluate stability. Additionally, bases produced by the same artisan are likely to have similar diameters in proportion to the rest of the statuette so that they would not fall.

- Arm length (AL). This is the (approximated) geodesic measurement between the identified joint of the arm (near the neck) and the end of the hand, i.e., the point attached to the held object or the body, passing on the "exterior" of the arm itself (the idea is to understand if it could come from one set of similarly made clay cylinders). In this case, extraction evaluates the presence of standards in preparing the statuettes' single parts and in the assembly of the statuette.

- Head length (HL). This aims to understand if the creators applied any standards to produce heads and if any quantitative relations exist between the bodies' several parts. For moulded heads, we extracted measurements to preliminary evaluate the heads' association with specific moulds.
- Weight (W). The weight (in grams) helps to identify a pattern in using a specific amount of clay to produce the statuettes and if there is a relationship between dimensions and weight.

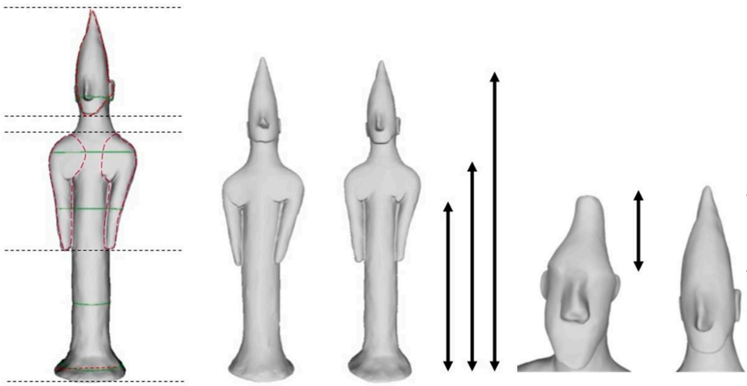

Figure 4.15
Measurements and proportions of the statuettes to compare (Vassallo©).

	AI881	AI883	AI888	AI88	AI92	AI96	AI99
total height	22.18612	21.65699	19.62592	25.23407	19.21029	17.92015	20.62827
arm length	6.88639	7.56927	8.41697	12.76251	7.48594	8.08636	7.88451
base diameter	5.52903	4.96282	4.96149	6.84970	5.77254	6.26190	6.09015
head's height	4.51550	4.61459	5.53982	5.96950	4.09826	3.79877	4.28612
Arm length/total height	31%	35%	43%	51%	39%	45%	38%
base diameter/total height	25%	23%	25%	27%	30%	35%	30%
head's height/total height	20%	21%	28%	24%	21%	21%	21%
arm length/base diameter	125%	153%	170%	186%	130%	129%	129%
Arm length/head's height	153%	164%	152%	214%	183%	213%	184%
base diameter/head's height	122%	108%	90%	115%	141%	165%	142%

	AI1587	AI771	AI130	AI1223	AI886	AI142	AI759
total height	27.68871	26.95801	26.44599	26.53270	25.34163	25.34961	24.09683
arm length	8.44014	10.33891	8.04144	9.66433	7.74583	8.02187	7.91964
base diameter	5.47373	4.58893	5.31288	5.47725	4.55938	4.26202	5.03348
head's height	7.32233	10.23803	8.53237	5.64863	7.56911	10.27163	8.07345
Arm length/total height	30%	38%	30%	36%	31%	32%	33%
base diameter/total height	20%	17%	20%	21%	18%	17%	21%
head's height/total height	26%	38%	32%	21%	30%	41%	34%
arm length/base diameter	154%	225%	151%	176%	170%	188%	157%
Arm length/head's height	115%	101%	94%	171%	102%	78%	98%
base diameter/head's height	75%	45%	62%	97%	60%	41%	62%

Figure 4.16
Extracted measurements and ratios of wheel-made (a) and handmade figurines (b) (Vassallo©).

We take measurements, normalised in centimetres, by semi-automatically slicing the 3D model.[196] Initially, we automatically extracted measurements belonging to the wheel-made group because they present distinctive characteristics due to their production techniques. We then use this as a test-bed experiment for the specific research question related to standardisation to be applied to the remaining statuettes.

I created a table for the groups investigated, divided into fields according to the measured body parts (Figure 4.16). We calculated the average (mean), minimum and maximum values.

The total height of the wheel-made figurines averages 20.02 cm. Some present a height oscillation towards 21-22 cm, and in some cases, below 20 cm. Only one reaches a height of 25 cm (A.I.88). Specifically, the wheel-made figurines' height ranges from a minimum of 17.74 cm to a maximum of 25.23 cm (17.74 < 20.02 > 25.23). Due to issues related to the digital acquisition of the statuettes (see Chapter 3), I 3D scanned handmade objects that ranged from 20 cm to 30 cm. I disregarded such criteria for the wheel-made figurines when making selections due to their smaller number and consistent height.[197]

The extracted measurements of the wheel-made figurines' base diameter show an average of 5.78 cm. The variation is in millimetres, with a maximum value of 6.84 (attributable to the A.I.88 figurine) and a minimum value of 4.96 cm.

In the case of the arms' length, the measurements present some slight differences. The lengths average 8.24 cm, with a value that goes from a minimum of 6.78 cm to a maximum of 12.76 cm (the latter is the arms' length of the A.I.88 figurine).[198] Even considering the highest value, the sample variance is 1.04 cm.[199] The differences highlight some qualitative appearances of those body parts. For instance, the arms with a simple cylindrical shape usually present smaller measurements between 6.78 cm and 7.50 cm or slightly over (e.g., A.I.881, A.I.876, A.I.877, A.I.872, A.I.883, A.I.1499), while more carefully shaped arms measure over 8 cm (e.g., A.I.88, A.I.83, A.I.113, A.I.1660, A.I.3893, A.I.1535).

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[196] Special care was taken to measure distances between horizontal projections of points onto a vertical plane.

[197] For a more detailed explanation of the selection process, see Chapter 3.

[198] Even omitting the outlier value represented by the A.I.88 figurine, the average is similar and measures 8.12 cm

[199] The variance describes how far each number in the sample is from the mean (average). In practice, it often shows how much something changes.

Concerning the heads, in this phase of the analysis, the semi-automatic extraction considered the entire structure of those body parts, including the tenon/neck. The purpose was to understand how this whole measurement interacts with the others in a system that tests the presence of ratios or rules for creating standardised products. Consequently, we cannot use this specific measurement to locate similarities or the same production tools. Head height averages 4.36 cm, with a minimum value of 3.08 cm and a maximum of 7.34 cm. Seven statuettes present the highest values (A.I.83, A.I.88, A.I.85, A.I.113, A.I.888, A.I.1250, and A.I.1507). The remaining measurements show a slight variation between 3.08 cm and 4.61 cm.

Next, I compared the previously extracted and analysed measurements in search of ratios that can provide information on the possible relationship between them and prove the existence of rules and standards in producing these figurines. We tested different combinations (Figure 4.16) and identified homogeneous relationships between three of the six ratios calculated. In particular, the homogeneous relations are visible in the ratio of Arm Length/Total Height, Base Diameter/Total Height, and Head Height/Total Height. The remaining proportions (Arm Length/Base Diameter, Arm Length/Head Height, and Base Diameter/Head Height) present variable percentages. They are utterly unrelated in constructing the figurines and creating a system of proportions.

The automatically extracted measurements of the handmade figurines show greater variability than the previous group: their heights range from a minimum of 16.62 cm to a maximum of 27.68 cm, with an average (mean) of 22.19 cm (16.62 < 22.19 > 27.68). The handmade statuettes range in height between 20 and 30 cm for reasons related to their digital acquisition (see Chapter 3).

Similarly, concerning the base diameter, the extracted measurements of these parts show variable values, with an average of 4.30 cm. The maximum variation is 5.47 cm (attributable to the A.I.1342 figurine), and the minimum variation is 1.99 cm (attributable to the A.I.195 figurine).[200]

The handmade figurines' arms range from 5.06 cm to 10.33 cm, averaging 7.13 cm.

The last analysis focuses on the heads. Like in the previous group, these extracted measurements include the neck to understand how its entire structure interacts with the remaining measurements (e.g., total height, arms' length) and infer the presence of rules or standardisation in the production of

[200] Although the minimum value is due to the lack of the last part of the figurine's base, it is not expected a much higher dimension, considering the total height and its shape.

these figurines. The head heights have a high variability: an average value of 6.88 cm, with a minimum value of 3.83 cm and a maximum of 10.27 cm.

We also calculated the ratios between the extracted measurements. As in the previous group, there are more homogeneous relationships between some measurements concerning others, and here the results are similar to those obtained by analysing the measurements individually.

For the handmade figurines, homogeneity in the Arm Length/Total Height ratio is visible, and we can assume the intent to create human figures with homogeneous and proportionate measurements. Nevertheless, it is possible to identify variations that group figurines with quantitative and qualitative similarities. For instance, some figurines (e.g., A.I.1590, A.I.271, and A.I.1548) show the same body part measurements, and we can see the same patterns for the analysis of the ratio between Arm Length/Total Height, Base Diameter/Total Height and Head Height/Total Height. The remaining proportions (Arm Length/Base Diameter, Arm Length/Head Height, and Base Diameter/Head Height), as in the previous group, are highly variable and completely unrelated to the construction of the figurines.

The weighted analysis provides information on the production and implies the existence of fixed rules for this measurement or variations according to other factors (e.g., height). It is an essential element for production because it connects with the type of material, the quantity used, and the production process. For these reasons, weight proved beneficial for classifying and interpreting the figurines under study.

We obtained all the previously mentioned measurements by extracting them from their 3D models. However, since it was problematic to compute the weight of the statuettes automatically from their 3D models for issues connected to the exact calculation of all statuettes' clay average density and for the lack of some figurines' 3D internal representation for extracting the precise volume (Scalas et al. 2018: 258), I measured the weight with standard digital scales. Next, I collected and used heights and weights for descriptive statistics for each production technique (Figure 4.17). The statuettes average 259.6 gr for the handmade and 238.8 gr for the wheel-made.[201] By correlating height and weight, the analysis shows a scattered distribution, and therefore a higher variability, of the handmade than wheel-made, which indicates a closer distribution and higher homogeneity.

[201] It is important to underline that some of the sampled statuettes lack information about the weight due to logistics reasons (12 statuettes for the handmade and 4 for the wheel-made).

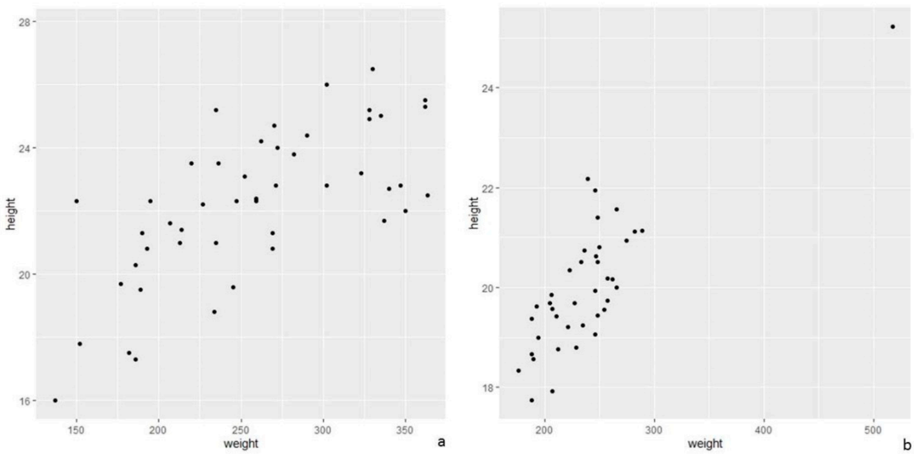

Figure 4.17
Scatterplot of the two variables “weight” and “height” according to the production technique, handmade (a) and wheel-made (b) (Vassallo©).

Shape analyses applied to statuettes' heads

In Chapter 2 (Table 2.4, p. 61-62), I mentioned how, through a qualitative method, Gjerstad et al. (1935) showed the presence of five moulds within the Ayia Irini Type 7 statuettes, but that Gjerstad did not document the correspondence between the moulds and the statuettes. Reviewing Karageorghis et al. (2009), Fourrier (2010) suggests using precision measurements of moulds for a more reliable categorisation of the small Cypriot coroplastic. In this way, Fourrier underscores the need to apply technology and quantitative methods to traditional archaeological research.

Therefore, further archaeological sub-questions arose, including: How many moulds can be quantitatively identified in this research sample? How many, and which artefacts come from the same mould? Is it possible to locate a relative ‘chronological sequence’ between the different moulds? Is it possible to identify production patterns and sub-groups within the handmade artefacts? To a broader extent, can these characteristics help further analyse and classify the Ayia Irini production and provide new insights into its interpretation and its relative chronological relations?

We analysed additional descriptors to solve these specific archaeological questions and identify (same, new, or different?) subgroups. It is possible to perform various experiments to search for meaningful descriptors that allow identifying elements useful for a shapes' clustering that, in turn, could suggest a common production.

We can apply this experiment to the heads, both moulded[202] and handmade. Such a procedure results in several clusters, advances hypotheses, and raises further questions. Clusters of heads may relate to production methods (handmade or moulded). For instance, the extraction of multiple transversal slices and their comparison can help identify similarities among the artefacts for sub-grouping them: the multiple transversal slices can be applied to the Ayia Irini statuettes' heads to identify their production technique and classify them accordingly (Scalas et al. 2018: 257).

The first of the above-mentioned archaeological research questions concentrates on the possibility of automatically and quantitatively identifying the number of moulds (for creating the sampled Type 7 statuettes heads) and linking the mould with specific artefacts. This method might help identify a 'chronological sequence'[203] between the different moulds. After this first step, the question also extends to the handmade heads. It focuses on the hypothesis of automatically and quantitatively identifying similarity groups, which might indicate the presence of the same hand, workshop, or provenance.

Identifying the number of different moulds used and recognising the artefacts produced with each of them is a typical classification problem in archaeology. It is particularly complex when the number of classes is not known *a priori*. To this aim, we had to identify proper shape descriptors for the heads and a similarity metric based on those descriptors to cluster the most similar ones into groups. Initially, we decided to compute descriptors on a series of slices of the figurines' heads. Vertical and horizontal slices through the nose-tip produced the best results (Figure 4.18). They helped divide the collection into two possible groups: a cluster presenting common and qualitative similarities, with a set of similar but more variable characteristics.

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202 Concerning ancient mould-made terracottas, Nicholls states, '*were mass-produced*' and underlines that, like coins, were created in significant amounts and according to a mechanical process. For this reason, a classification of these artefacts has to take into consideration their manufacturing methods and process (Nicholls 1952: 219).

203 "Series", as named by Nicholls 1952.

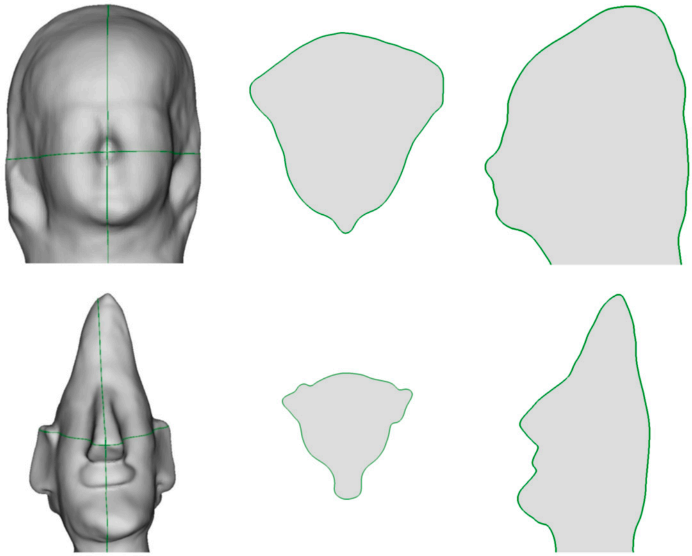

Figure 4.18
Vertical and horizontal slices through the nose tip of the statuette A.I.87 (above) and A.I.28 (below). The slices discriminate between two groups we might attribute to moulded and handmade heads (Vassallo©).

Topological skeleton/medial axis

We further analysed the head, comparing the slices through the corresponding approximate topological skeleton or medial axis.[204] The question is, why add the topological skeleton/medial axis to the slices for the comparison? Cannot overlapping two slices be enough to detect the similarity between two shapes? Does a topological skeleton/medial axis provide more information regarding simple slices?

The medial axis/topological skeleton of an object is the set of all points having more than one closest point on the object's boundary. It is a property characteristic of any shape. Theoretically, it follows that if two have the same medial axis, they are equal.

In general, overlapping slices can be helpful as a first step in similarity identification. In particular, the number of points necessary to describe a shape is much higher than that needed to describe a topological skeleton.

[204] The concept of the medial axis was, for the first time, introduced by Blum (1967) as an efficient tool for the recognition of biological shapes. Literature reports on some experiments that used the topological skeleton and medial axis (Dougherty 1992; Jain et al. 1995: 55; Gonzales & Woods 2001:650).

Moreover, the medial axis is part of the so-called **graph-based descriptors**. In shape analysis, there is extensive literature on the efficient comparison of graphs for shape similarity retrieval and comparison (Zeckey & Langner 2020). Figure 4.19 compares slices in pairs from two Ayia Irini statuettes (A.I.866 and A.I.877); the visible internal subdivision represents their corresponding approximate topological skeleton/medial axis.

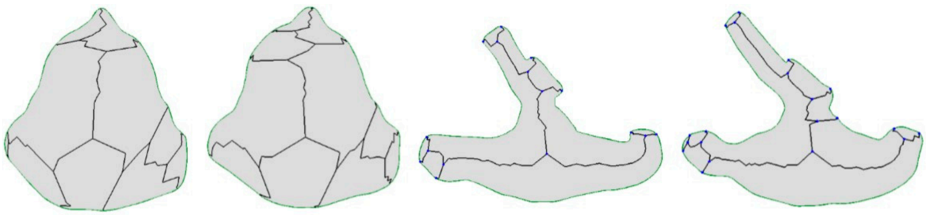

Figure 4.19
Similarity tests on heads (left) and bodies (right) of two statuettes, A.I.866 and A.I.877 (Vassallo©).

To evaluate the quality of the comparison, we performed slices on both heads and bodies. The preliminary results show significant similarity between the approximate skeletons/medial axes. The current calculation is an approximation; therefore, this comparison is still qualitative. Adding the quantitative aspect will give further information and help measure the similarities between the objects compared (Scalas et al. 2018a; Scalas et al. 2018b; Vassallo et al. 2019). The medial axis captures the geometric and topological information and simplifies the shape representation. Still, we cannot easily compare them since the descriptors represent shapes as vectors of numbers. We need further development for the quantitative comparison of the slices (Figure 4.20), which requires recalibrating the descriptors. Since this falls outside of the aims and purpose of this dissertation, we devised a solution that uses existing descriptors.

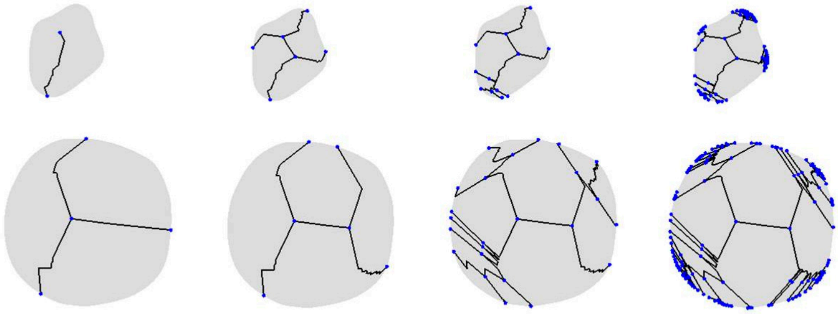

Figure 4.20
Quantification test of the extracted medial axis (skeleton of statuettes' slices) (Vassallo©).

Hausdorff distance

We used the *Hausdorff* distance as an intermediate quantitative value to find similarity for comparative purposes. The distance analyses the differences and similarities of the geometries. In mathematics, the *Hausdorff distance* (also known as *Hausdorff metric*) measures how far from each other are two subsets of a metric space. According to this measure, two sets are close if every point of a set is close to some point of the other set. In computer graphics, the *Hausdorff distance* computes the geometric differences between two 3D models: it can measure the difference between meshes of two 3D objects or between different representations of the same 3D object.

Cignoni et al. (1998) developed a *Hausdorff distance* tool, and then they integrated it as a filter in MeshLab (*Filters: Sampling->Hausdorff Distance*). This tool computes the distance between two meshes, sampling one of the two and finding for each sample the closest point over the other mesh. In other words, it is the greatest of all the distances from a point in one set to the nearest point in the other set. Hence, we applied the MeshLab filter computing the *Hausdorff distance* to all the heads of the statuettes sampled for this research.[205] The similarities matrix obtained from the comparison of all the heads shows a sequence that ranges from most similar to most different. For example, if we look at the first line of the matrix highlighted by the red rectangle (Figure 4.21), it clearly shows the passage to different kinds of heads.

---

205 MeshLab for computing the *Hausdorff distance* formula uses a sampling approach taking a number of points over a mesh *X* and searching for each *x* the closest point *y* on a mesh *Y*. The tool computes only the one-sided version of the formula, leaving the user the task of obtaining the maximum of the two. The result can be affected by the number of points the user takes over X can affect the result, but it is possible to follow some approaches to obviate any issue.

	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
1		AI101	AI102	AI99	AI872	AI111	AI1250_0001	AI868	AI1235	AI881	AI1660	AI1295	AI713	AI92	AI866
2	AI101	0	0,007872	0,008063	0,008096	0,008501	0,008546	0,008977	0,009177	0,009296	0,009896	0,009952	0,010164	0,010583	0,010777
3		AI102	AI872	AI101	AI1660	AI1250_0001	AI868	AI866	AI1235	AI445	AI92	AI881	AI1295	AI584	AI99
4	AI102	0	0,007663	0,007872	0,008171	0,008202	0,008918	0,009203	0,009276	0,009648	0,00995	0,010152	0,010182	0,010476	0,010975
5		AI105	AI109	AI1235	AI1485	AI877	AI96	AI1877	AI1128	AI1250_0001	AI99	AI883	AI880	AI870	AI872
6	AI105	0	0,00684	0,007452	0,00789	0,007975	0,008288	0,008423	0,008529	0,00856	0,008715	0,008831	0,008934	0,009056	0,00923
7		AI109	AI1235	AI105	AI1128	AI1485	AI99	AI111	AI1250_0001	AI872	AI1877	AI1205	AI1660	AI92	AI1295
8	AI109	0	0,006648	0,00684	0,007481	0,007973	0,008321	0,008923	0,008923	0,009555	0,009776	0,009989	0,010283	0,010335	0,010429
9		AI111	AI99	AI1235	AI1250_0001	AI101	AI872	AI109	AI713	AI1295	AI1485	AI1205	AI105	AI1128	AI881
10	AI111	0	0,007292	0,007717	0,007981	0,008501	0,008798	0,008923	0,009374	0,009427	0,009526	0,009863	0,009938	0,010102	0,010789
11		AI1128	AI1485	AI109	AI105	AI881	AI99	AI880	AI1877	AI1235	AI870	AI1205	AI245	AI111	AI713
12	AI1128	0	0,007388	0,007481	0,008529	0,008553	0,008672	0,008853	0,009398	0,009478	0,009738	0,009807	0,010099	0,010102	0,010285
13		AI113	AI83	AI88	AI85	AI1496	AI1499	AI3893	AI888	AI1535	AI580	AI1250	AI1871	AI876	AI881
14	AI113	0	0,010176	0,016123	0,019534	0,019968	0,024386	0,026292	0,026917	0,029606	0,029857	0,030007	0,037279	0,040439	0,044788
15		AI1205	AI99	AI880	AI1235	AI713	AI1128	AI111	AI109	AI96	AI105	AI1485	AI877	AI1250_0001	AI870
16	AI1205	0	0,009151	0,009405	0,009534	0,00961	0,009807	0,009863	0,009989	0,010238	0,010274	0,010774	0,011564	0,011618	0,011692
17		AI1235	AI109	AI872	AI1250_0001	AI105	AI111	AI868	AI1877	AI99	AI101	AI102	AI1128	AI1660	AI1205
18	AI1235	0	0,006648	0,006977	0,007108	0,007452	0,007717	0,008066	0,008852	0,009059	0,009177	0,009276	0,009478	0,009529	0,009534
19		AI1250_0001	AI872	AI1235	AI868	AI1295	AI111	AI99	AI102	AI92	AI101	AI105	AI109	AI1877	AI1485
20	AI1250_0001	0	0,00678	0,007108	0,00749	0,007571	0,007981	0,008188	0,008202	0,00846	0,008546	0,00856	0,008923	0,009539	0,009903
21		AI1250	AI1535	AI580	AI1499	AI3893	AI888	AI1496	AI85	AI83	AI113	AI876	AI88	AI1871	AI880
22	AI1250	0	0,007684	0,00827	0,009243	0,011292	0,011705	0,014765	0,018805	0,025305	0,030007	0,037425	0,038194	0,041696	0,042482
23		AI1295	AI92	AI99	AI1250_0001	AI1485	AI881	AI872	AI713	AI111	AI105	AI101	AI868	AI102	AI109
24	AI1295	0	0,006021	0,006842	0,007571	0,007691	0,0082	0,00898	0,009344	0,009427	0,009725	0,009952	0,010061	0,010182	0,010429
25		AI1485	AI881	AI99	AI1128	AI1295	AI105	AI109	AI713	AI92	AI868	AI111	AI1235	AI1250_0001	AI883
26	AI1485	0	0,007046	0,00726	0,007388	0,007691	0,00789	0,007973	0,007974	0,008886	0,009346	0,009526	0,009693	0,009903	0,010178
27		AI1496	AI1499	AI3893	AI888	AI1535	AI580	AI1250	AI83	AI113	AI85	AI88	AI1871	AI876	AI101
28	AI1496	0	0,011727	0,012742	0,013706	0,013729	0,014542	0,014765	0,018591	0,019968	0,02335	0,028044	0,036545	0,03699	0,041785

Figure 4.21
Data from the Hausdorff distance test applied to heads (Vassallo©).

Figure 4.22 establishes the similarity of the heads as quantitatively measured using *Hausdorff distance*. The sequence of the statuettes shows the passage to different heads. The distance computed between A.I.101 and A.I.102 (mean: 0.007872) becomes higher between A.I.101 and A.I.99 (mean: 0.008063) and higher and higher between A.I.101 and A.I.872 (mean: 0.008096). The sudden difference in the sequence in terms of distance in the matrix between A.I.101 and A.I.713 (mean: 0.010164) suggests a change in the shape of the heads; similarly, the distance between A.I.101 and A.I.866 (mean: 0.010777) indicates an increase in the dimension and therefore a change in the heads' shapes.

This analysis's results are effective, especially concerning the capacity to attribute a similarity sequence to the heads of the sampled statuettes, particularly evident for the artefacts produced with moulds. This analysis demonstrates a quantitative distance between the meshes, a visual representation of results, and similarity among the heads.

Nevertheless, a successive similarity clustering based on these quantitative results would be too sensitive to outliers (noise) due to possible errors in the registration of the 3D models. Therefore, we need to conduct further quantitative analyses and eventually integrate the results with those obtained from the *Hausdorff distance* to identify a possible chronological production sequence.

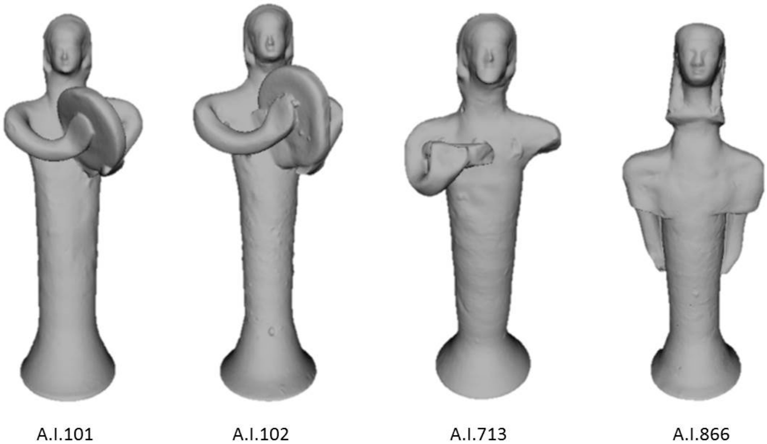

Figure 4.22
Visual representation of part of the sequence computed by the Hausdorff distance. The size change of the heads, from the figurine A.I.101 and A.I.102 without a beard to A.I.713 with a clay-added beard to A.I.866, shows a different, longer shape (Vassallo©).

MeshSIFT

In the successive experiment, we analysed the material using a more effective quantitative approach, focussed on the heads of the statuettes, and based on **local-keypoint-based-descriptors**. Specifically, the shape analysis relies on MeshSIFT (Smeets et al. 2013) and DBSCAN (Ester et al. 1996). The procedure consists of finding correspondences between the heads, matching similarities, and then clustering based on a similarity score. We employed MeshSIFT to extract and search for correspondences between feature points and DBSCAN to cluster the most similar heads for this task. The pipeline consists of the following steps: first, we selected and extracted the head from the figurine mesh; second, we used two state-of-the-art algorithms to 1) assess the similarity score and 2) cluster similar items into classes. The experiments focus on the similarity of heads: it consists of applying the same pipeline to different subsets of the dataset. The aim is to group figurines whose heads are most similar. The resulting classes should represent figurines produced with the same mould or created by the same hand.

Heads identification

The 3D models of the statuettes present some issues that we had to solve before the analysis. We chose to focus on heads because the body shapes are too variable and affect the experiments' results. We started by separating the head from the whole body mesh; Type 7 statuettes required an additional operation to perform this function. Differences on the backs of the heads indicate a front-only mould.[206] So, we used only the front half of the head for the experiment. We manually segmented using MeshLab (Cignoni et al. 2008).[207]

Moreover, pre-processing (or normalisation) is necessary before applying 3D descriptors analysis on the shapes. In this phase, we conduct operations such as positioning and orientation, scaling, and alignment.[208] First, heads must be positioned along the same axis. Shape orientation consists of rotating the shape by a given angle to place it in standard orientation. Then we align and scale the heads for comparison (Biasotti et al. 2016: 9). We performed the alignment using the common ICP (Iterative Closest Point) procedure with manual intervention. Additionally, some meshes contained defects (e.g., isolated vertices, duplicated faces) that we fixed during pre-processing with a MeshLab-based script and a finer ReMesh[209] (Attene & Falcidieno 2006) post-processing for those meshes that still had imperfections.

206 Statuettes, or their parts, were generally made with single or bivalve moulds. In the production of heads, for example, such a procedure can be seen observing their back. In some cases, the back part can be just a simple and smooth piece of clay obtained by pressing on a working surface, or a more rounded one to give the impression of a cranium's curvature; in other cases, we can observe a precise and modelled back that demonstrate the use of a bivalve mould.

207 We carried out a parallel test to automatically segment the head part: we used a set of parallel horizontal cutting planes (3D models are consistently aligned with the up-vector along the positive Z axis) to analyse the evolution of the length of intersection curve between the planes and the mesh, starting from the upper-most plane. An abrupt length increase should identify the shoulder level, and proper post-processing could select the head nicely in most cases.

208 Invariance to transformations is sometimes needed to allow the similarity assessment to be independent respect to orientation or scaling. In general, invariance properties can be already characteristics of the shape descriptors used (Biasotti et al. 2015a) or can be set *a priori* thanks to some normalisation operated on the objects we have to analyse (Koutsoudis et al. 2010)

209 http://remesh.sourceforge.net/

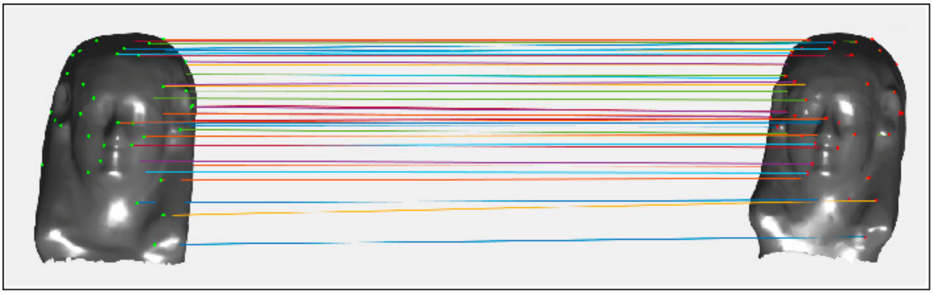

Figure 4.23
The output of the test with the coupled features identified by the software (Vassallo©).

Similarity assessment

Therefore, we applied MeshSIFT to assess the similarity between pairs of head meshes. Smeets et al. (2013) first developed MeshSIFT for expression-invariant face recognition. Beyond that application, the one by Zhao et al. (2017) for craniofacial reconstruction and Giorgi et al. (2015) for weight gain assessment. To my knowledge, this is the first time this technique has been applied to Cultural Heritage and archaeology.

Although the invariance to face expression is not a requirement in the current setting, we employed this method because the dataset is coherent with its original application on faces/heads, and because of its robust incomplete data (open meshes represent the heads). Moreover, the method achieves a good recognition rate (Veltkamp et al. 2011), and an open implementation in Matlab is available online (Chris et al. 2019).

Practically, MeshSIFT shows a set of salient points (*keypoints*) on the two compared mesh surfaces as multiscale extrema of the Mean curvature; then, it assigns each *keypoint* a feature vector describing the local surface around the point. Finally, it computes correspondences between the two faces by linking the *keypoints* according to the similarity between their feature vectors (Figure 4.23). Four main steps compose the procedure (Table 4.4).

Table 4.4
Steps of the procedure

Step	Operation
1. Feature points extraction	The algorithm locates the salient points on the face as the mean curvature extrema in scale space
2. Orientation assignment	The algorithm assigns an orientation to each one of the extracted salient points
3. Feature vector composition	Concatenating histograms of shape indices and slant angles in a feature vector which acts as a descriptor for the face, describe the neighbourhood of each salient point
4. Similarity computation	The face-to-face feature vectors comparison searches for correspondences. The number of the found correspondences gives a good estimate of the similarity between the two faces.

In brief, the number of matched pairs estimates how similar the two meshes are. As a measurement of similarity between two faces, the literature suggests using the number k of matched keypoints (Veltkamp et al. 2011).[210]

The comparison of n heads in pairs produces a n × n matrix M of integers such that Mi,j contains the similarity value sij between face i and face j. Within this matrix, the maximum values by row and column lay on the diagonal (self-similarity) (Figure 4.24).

In the first stage, the range of similarity values between faces/heads differs greatly. For instance, in the experiments run on Ayia Irini's 103 items, the self-similarity value ranged between 1466 for the model of the statuette A.I.1249 and 160 for the model of the statuette A.I.1295. Most importantly, the clustering algorithm works with distances among elements rather than similarities for classification purposes. For these reasons, we needed to reverse the data and normalise the similarity scores for each model (with the maximum being the self-similarity value) in the range [0,1]. With the normalisation (Min-Max scalar) approach, we scaled data to a fixed range, usually 0 to 1. This operation aims to have a smaller standard deviation, which can suppress the effect of outliers.

Next, we reversed data to represent the distance between two heads/faces as dij = 1 - sij. More specifically, we computed the normalised distance dij

210 A further calculation could be the normal of the vector that corresponds to the distance between the features, but this calculation does not diverge from the result very much. Preliminary tests on a small group of five moulded faces (before on the faces exclusively and then on the whole cranium), considering both the normal of the vector and the 'k' value calculated by the software, provided the same 'similarity' values. For instance, the comparison between the statuettes A.I.1535 and A.I.1499 heads are in the first case 1,2803; k=37 and in the second case 1,2802; k=37.

between i and j by applying the following formula to each entry sij of the matrix:

$$\frac{S_{ij} - \underset{i}{min}(S_{ij})}{\underset{i}{max}(S_{ij}) - \underset{i}{min}(S_{ij})}$$

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	240	19	24	0	1	2	2	2	0	2	2	23	1
2	19	214	14	0	0	0	3	0	1	1	1	17	1
3	24	14	217	0	1	0	2	0	0	0	1	22	0
4	0	0	0	87	9	6	6	10	3	7	4	0	3
5	1	0	1	9	128	14	9	16	20	12	6	3	15
6	2	0	0	6	14	107	14	13	10	9	10	2	12
7	2	3	2	6	9	14	128	9	17	8	10	2	13
8	2	0	0	10	16	13	9	134	19	8	5	0	12
9	0	1	0	3	20	10	17	19	143	17	17	2	20
10	2	1	0	7	12	9	8	8	17	127	12	0	9
11	2	1	1	4	6	10	10	5	17	12	177	2	7
12	23	17	22	0	3	2	2	0	2	0	2	203	1
13	1	1	0	3	15	12	13	12	20	9	7	1	133

Figure 4.24
Example of the matrix produced: once we computed the correspondences between pairs of faces with MeshSIFT, we saved the resulting number of found correspondences in an Excel table (Vassallo©).

Classificatory approach: clustering and organising similarities

As previously mentioned, to extract useful information from the similarity calculation, it is necessary to organise those results properly. This organisation is done through a clustering approach. Cluster analysis (or clustering) is used to group (cluster) items based on the distribution of specific shape characteristics, grouping a set of objects so that they are more similar than those objects clustered in other groups. This operation can help understand and interpret the categorisation, for instance, of a collection of (3D) models after a geometric analysis.

Several surveys and studies of clustering techniques are available in the literature (Xu & Wunsch 2005; Rokach & Maimon 2005; Moitinho de Almeida 2013: 66 et seq.). A stumbling block of these methods is the need to know, *a priori,* the number of clusters. There are different clustering methods: i) Connectivity-based clustering; ii) Centroid-based clustering; iii) Density-based clustering.

The first method, also known as hierarchical clustering, works on the concept that objects relate more to closer objects than distant ones. According to this principle, the algorithms within this method join objects to form clusters based on their distance. The result is not a unique subdivision of the dataset but a hierarchy from which the operator has to choose proper clusters. Moreover, these algorithms do not handle outliers (noise) well.

Instead, in centroid-based or *k*-means clustering, a central vector that might not be a dataset member represents the clusters. In this case, *k* sets a number of clusters, and the *k-means* clustering algorithm optimizes the result: it finds the *k* cluster centres and allocates the objects to the nearest cluster centre, such that the squared distances from the cluster are minimized. The disadvantage of this method is that it is necessary to specify the number of clusters-*k*- in advance and that, by assigning an object to the nearest centroid, the clusters will be similarly sized, leading to possible inaccuracies.

Density-based clustering defines clusters as areas of high density separated by regions of low density (indicated by noise). In this context, the number of points within a specified radius defines the density.

In summary, traditional clustering techniques may not be sufficient to achieve accurate results if applied to arbitrary shape clusters. Partitioning algorithms, e.g., *k-means* algorithms (MacQueen 1967), work on assigning the number of clusters in advance. They do not consider the presence of outliers, assigning the items to a cluster even if they do not belong to any of them. Therefore, I have chosen to apply a density-based clustering method to my shape analysis results. Most clustering methods need to know *a priori* the number of clusters.[211] Although these methods are the most used, I decided to apply a non-assisted clustering method, where it is unnecessary to set several clusters in advance. For research purposes, a different method would be more suitable: one based on the notion of a "proximity'' of the elements in the clusters. Indeed, these other kinds of methods have the peculiarity of being independent concerning the number and shape of clusters, the order of the elements and noise. Unfortunately, a unique choice of proximity parameters could not be effective in case the space presents different local densities (Biasotti et al. 2016b:23). Still, an unsupervised method is more flexible since it does not need any prior information.

One of the unsupervised methods based on proximity and widely used is DBSCAN (Density-Based Spatial Clustering of Applications with Noise)

[211] It is necessary to previously set clusters of the items (and parts of the items) according to described and justified classes. The aim of the study, not only the homogeneity to that class, should be the term of evaluation that a cluster of types is correct. In few words, it is necessary to evaluate not the material as it is, but the reason for that choice, such as functional, "emic", space-time (see Chapter 1, p. 5 and the "typological debate" faced by many scholars in classification in archaeology and anthropology, e.g., Palincaş 2005)

(Ester et al. 1996).[212] DBSCAN is a density-based clustering algorithm. It does not require knowing the number of clusters in advance. It can be employed to filter noise (outliers) and discover clusters of arbitrary shape. It is available from Matlab R2019a and is a commonly used method in Cultural Heritage (Kyriakaki et al. 2014; Bi et al. 2014; Makantasis et al. 2016; Torrente et al. 2018; Ellefi et al. 2018; Grabowski et al. 2018).[213]

Heads clustering

The second step of the pipeline is to cluster heads/faces based on their normalised distance. We applied the DBSCAN algorithm to the first three components of the eigenvectors.[214] Then we extracted from *M* (the normalised data), allowing a spatial reduction of the data and making it visualisable.[215]

DBSCAN depends on two parameters to determine the clusters: the minimum number of points to define a cluster or dense region (set to 1); and the value of the threshold ε, which represents the maximum distance at which a point can be considered part of a cluster (it relates to the density of clusters and affects the clustering granularity). Therefore, higher values of ε determine few, huge clusters; conversely, a smaller ε will produce smaller sets. If ε is not set, the algorithm self-estimates this parameter.[216]

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[212] Another method used in Cultural Heritage and similar to DBSCAN is OPTICS - Ordering points to identify the clustering structure (Ankerst et al. 1999). In Cultural Heritage, Biasotti et al. 2015 adopted a similar unsupervised cluster technique based on a dominant sets' concept.

[213] Other applications of density-based spatial clustering (DBSCAN, specifically) can be found in other fields, such as urban planning studies (Kisilevich et al. 2010), geospatial concentrations for points-of-interest patterns finalised at business and policymaking (Lee et al. 2014), archival data management (Bron et al. 2014) and tourism distribution (Koutras et al. 2019).

[214] Eigenvectors are a special set of vectors associated with a linear system of equations, i.e., a matrix equation (Marcus & Minc 1988:144).

[215] We used these triplets also as coordinates to plot heads in the score space. Specifically, we created 3D scatter charts (or XYZ plots) with Matlab and Plotly (see fig. 4.25 - 4.30).

[216] The concept behind is the following. A point q is density-reachable from a point p if their distance is less than a specified threshold ε and if p is surrounded by a sufficient number of points. In this way, the density-connectivity can be stated as two points, p and q, are density connected if there exists a point o, such that both p and q are density-reachable from o (the latter definition guarantee that the points on the boundary of the clusters are grouped with those in the interior). So, any cluster in the database will satisfy the following properties: a) each pair of points in the cluster are mutually density-connected; b) if a point in a cluster is density connected to another point, that point is part of the same cluster.

We assessed different values of ε. Since we normalised the values in the range [0,1], we arbitrarily imposed that the maximum distance between points in the same cluster should be below 10% of the maximum distance (therefore, 0.1). Some values were chosen by heuristics (we carried out tests having as ε value 0.25, 0.01, 0.075, 0.07, 0.06 and 0.05).

We also used an *average distance* inside a cluster that we evaluated by extracting the *k* nearest neighbours (where *k* is the size of the cluster we expect) for each point and then computing the average of the mean distance between them. The knn-search algorithm provided by Friedman et al. (1977) and available on Matlab was used for this scope. From now onwards, we will define this value as *knn-ε*.

Moreover, the self-calculated *ε* provided by DBSCAN was used. Nevertheless, during the experiments, we observed that the 0.1 and the DBSCAN chosen threshold do not always provide satisfying results. For this reason, we used the *knn-ε* threshold to obtain the following results.

The following part describes three experiments that compare the Ayia Irini heads. The aim is to obtain quantitative information useful to analyse and interpret their manufacturing for classification purposes. The analysis concentrates first on moulded and handmade heads separately and then on the whole set.

Experiment 1: Intra-class clustering: moulded faces

The first experiment focused on the 43 moulded heads that Gjerstad et al. classified as Type 7 (1935).[217] The test aimed to understand how many moulds were used in the production and which statuettes were produced with each. As previously mentioned, we removed the rear part from the head to reduce the possible bias introduced by the stated differences: it was done by manually selecting and then removing the 3D vertices from the line that marks the end of the moulded part in the direction of the head back, using MeshLab (Cignoni et al. 2008). Therefore, only faces were taken into account in this test.

The clustering result allowed us to identify two main classes, named #1 “short hair” (32 items) and #2 “long hair” (11 items), according to their most apparent characteristic. In most of the tests performed with different values of ε, it is possible to identify the stable and constant presence of two separate and well-defined clusters within the “long hair” group. Particularly, using

[217] Probably, artisans applied the mould to the front head part of the figurine only, while they produced the bodies with the wheel, and they attached handmade limbs and accessories afterwards.

knn- ε as a threshold, the definition of two sub-groups within the “long hair” heads class and the other two sub-groups within the “short hair” heads’ class is visible. Figure 4.25 shows the clustering on the moulded faces, using as a threshold the value given by the average of the mean distances inside each group of neighbours, chosen using the knn-search. As can be seen, there are two farther clusters (the yellow and the green ones) that compose the “long hair” subgroup, while the purple and the light-blue clusters compose the “short hair” subgroup. Although the presence of these subgroups within the last cluster, the two “short hair” subgroups appear very close to each other. The pseudo-division could be due to a ‘disturbing’ variable feature (e.g., added clay for the beard).

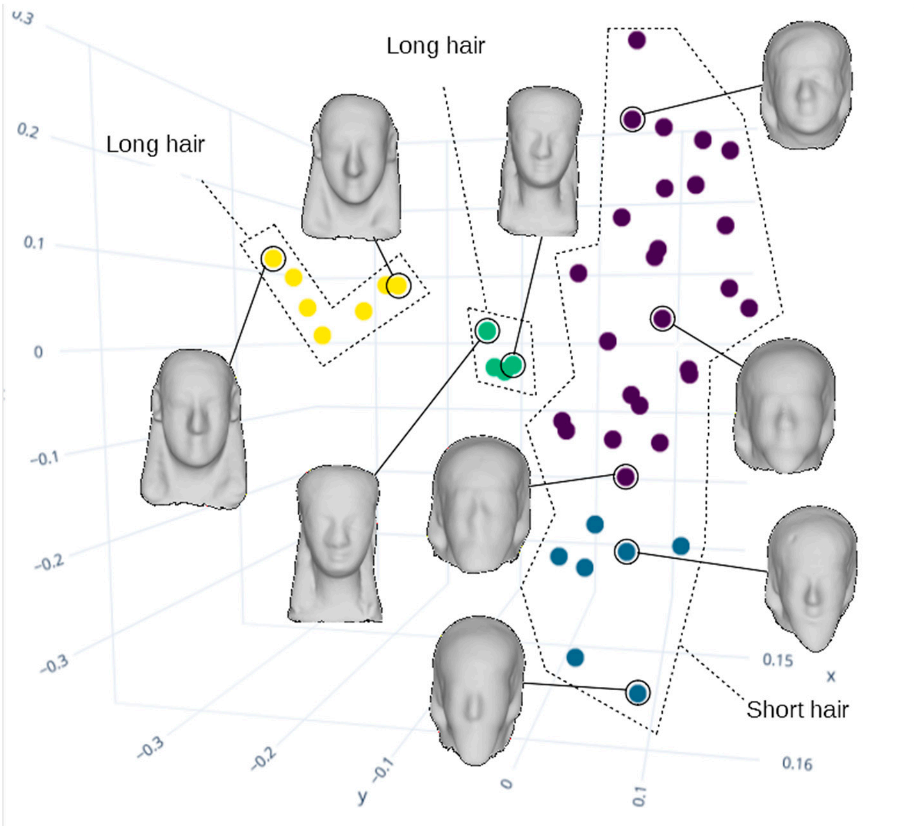

Figure 4.25
Experiment 1. Results of the analysis applying the knn- ε threshold (k = 9) on all the moulded heads/faces of the sample (Vassallo©).

As explained in Chapter 2, some heads belonging to Type 7 present handmade added features (13 heads out of the 32 "short hair"). The element consists of a small piece of clay that forms a beard, manually added after the head's moulding. Moreover, the test highlighted that the clay beard is present only in the "short hair" class.

Additionally, we noted a more definite subdivision between "heads with a beard" and "heads without beard" within the "short hair" heads class at finer clustering levels (namely, setting the ε at smaller values). These two sub-classes are not sharply delineated. The variability in the shape of the added beards obtained with the mere use of hands might bias the comparison process.

For this reason, and to understand if one or more moulds were used or if any differences can be identified, we decided to perform a further experiment on the "short hair" subset with three different settings:

- <u>Experiment 1a</u>: analysed 18 faces that have no added beards ("heads without beards");
- <u>Experiment 1b</u>: analysed 32 faces after manually removing the beards from the 14 "heads with a beard"[218];
- <u>Experiment 1c</u>: analysed 32 faces after manually removing the beards from the 14 "heads with a beard" and the chin from the 18 "heads without beard". The cut of the chin makes the group uniform.

Experiment 1a

The first experiment focuses on the 18 heads/faces, which have no added elements (i.e., beards). This first experiment aimed to check if any subdivision within the "short hair" heads/faces "without beards" appeared. By employing the *knn-ε* threshold (k = 9), one main group was created, with three items that deviated from the clustering (the three yellow dots in Figure 4.26), whose presence, possibly due to other contributing causes (e.g., different pressure, level of experience, overmoulding) needs further investigation. It is worth noting a specific case in the first experiment that is interesting at the technical level. Still, with consequences for the archaeological interpretation: the analysis categorises a moulded head belonging to the subcategory "short hair" (A.I.1249) as an outlier (noise) concerning the previously cited sub-groups. The result is exceptional since

[218] The 14 'heads with beard' are A.I.83, A.I.85, A.I.88, A.I.113, A.I.580, A.I.888, A.I.1250, A.I.1496, A.I.1499, A.I.1535, A.I.3893

this specific head presents external perimeter traces of the beard, currently lost: the automatic clustering recognised the difference for the remaining sub-groups, defining it but at the same time showing a reduction of the distance between the two macro-groups of moulded and handmade heads.

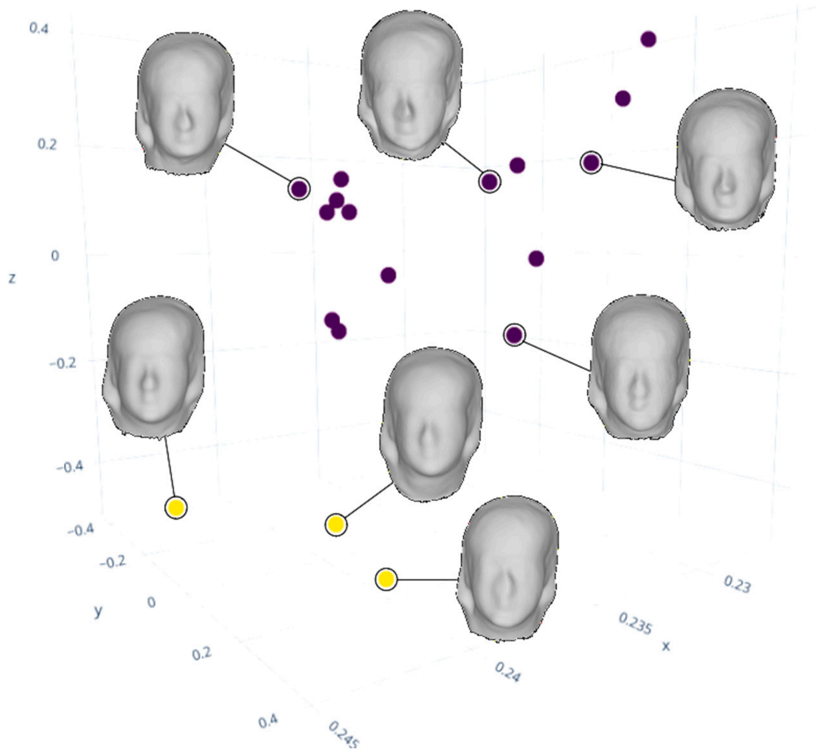

Figure 4.26
Experiment 1a. Results of the analysis applying the knn-ε threshold (k = 9) on the subset of "short hair" faces which do not have a beard (Vassallo©).

Experiment 1b

We performed the second experiment analysing all the 32 "short hair" heads/faces after manually removing the added element (i.e., beards) from the 14 "heads with a beard" with the *knn-ε* threshold (k = 9). The test aimed to identify any new clustering. The results show a definite sub-division between the 18 faces "without beards" and the 14 faces "with beards removed". Two items, identified by the yellow dots, slightly deviate from the two groups, but they are closer to the one of the 18 "without beard" (Figure

4.27). It is worth highlighting that one of the two heads is the A.I.1249, mentioned in the previous experiment. The division into two groups could be because the modified faces (those in which we eliminated the beard) present a lack. Technically, this division underlines how the automatic similarity-clustering algorithms might recognise the differences between a whole face and a partial one. Therefore, the recognition happened only on the upper part of the faces, creating a group *per se*, while all the "short hair" items belong to the same group.

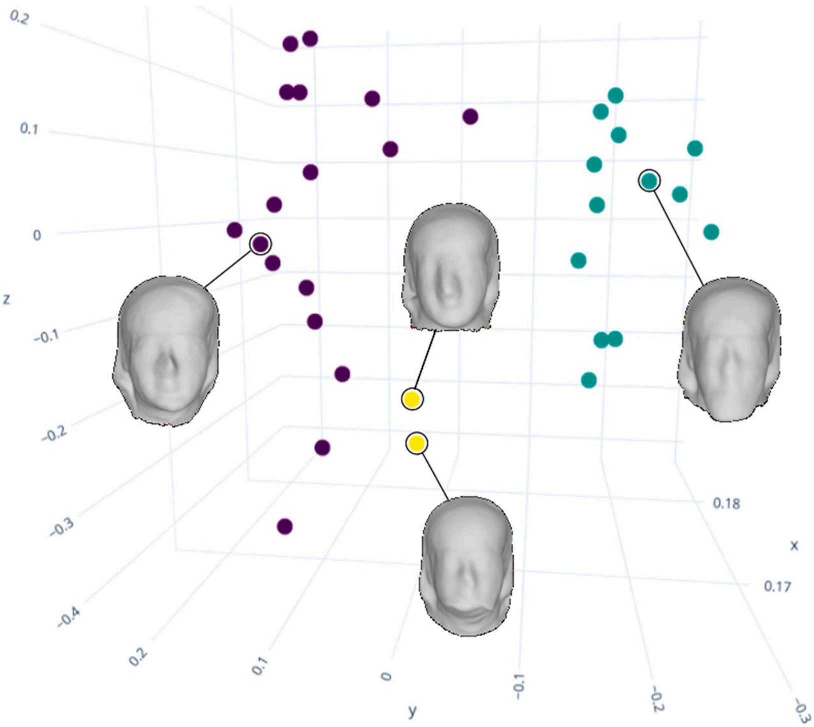

Figure 4.27
Experiment 1b. Results of the analysis applying the knn-ε threshold (k = 9) on the subset of "short hair" face after removing the beard from the faces that have it (Vassallo©).

Experiment 1c

The reduction of the analysed surface given by removing the beard could have forced the cropped faces into a new group. For this reason and to see if the results are nearly similar to the previous experiment, we decided to carry out another test by manually removing from the 32 "short hair" faces the chin area, bearded or not, to make them homogeneous and run with the *knn-ε* threshold (k = 9). The result of this experiment does not show any remarkable subdivisions in further classes: a big group is produced, with the presence of some small other aggregations possibly introduced by minor differences identifiable with different pressure of the clay on the mould during the production or the numerous mouldings no longer producing heads with clear and sharp details (Figure 4.28). For instance, as shown in the figure, the heads represented by the purple dots show a smaller, more 'defined' nose. Upwards (light green dots), the cluster is composed of much more 'undefined' noses.

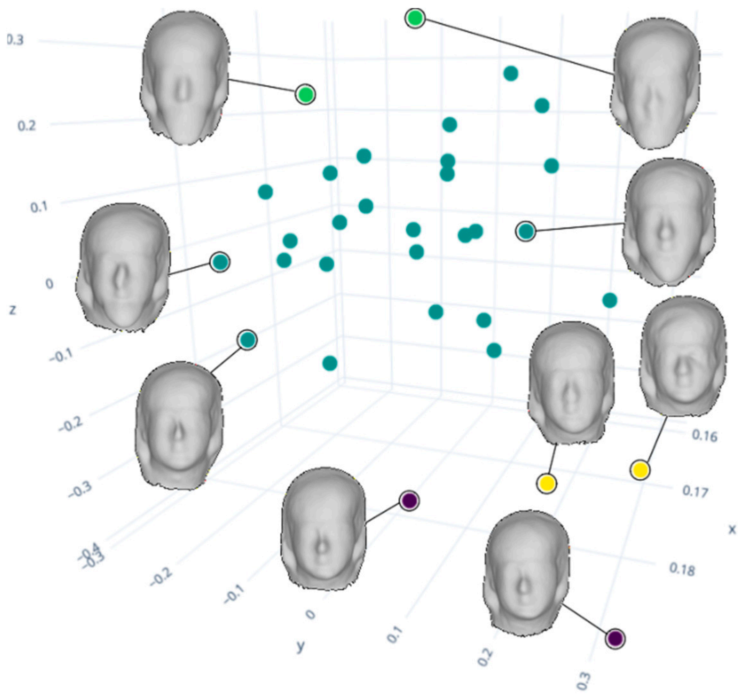

Figure 4.28
Experiment 1c. Results of the analysis applying the *knn-ε* threshold (k = 9) on the subset of the short hair faces from which we removed both the beard and the chin (Vassallo©).

Experiment 2: Intra-class clustering: handmade heads

The second experiment focuses on the handmade heads of the Ayia Irini sample chosen for this study. We decided to apply this method to the remainder of the sample based on the strong results from the moulded head experiments. Specifically, we applied the preceding approach to the sixty (60) handmade statuettes attributed by the original study to Types 5 and 6. Of course, these items are much more problematic than those analysed in Experiment 1: the geometric characteristics created by a hand production give rise to various variabilities that could complicate the analysis (e.g., lack of regularity, asymmetric faces). Unlike the previous experiment, which analysed only the front part of the heads (that is, the faces), in this case, the analysis concentrates on the whole head mesh. Keeping the entire shape originates from the fact that these heads are exclusively handmade, and therefore all their parts can provide hints regarding the production similarities operated by the artisans. We run the analysis of the handmade heads (Figure 4.29) with the *knn-ε* threshold (k = 10). The classification of these heads presents some outliers due to the previously mentioned variability; the automatic clustering grouped similar heads' shapes.

The current analysis highlighted some interesting results: by changing the value of ε during the experiment, definite sub-groups appeared (Figure 4.29). Significantly, sub-groups of statuettes with "long hat" heads, "short hat" heads, or "truncated hat" heads appear, and they keep their stability in all the clustering tests. This sub-division is particularly interesting because the algorithm operates on the head's entire shape and facial characteristics.

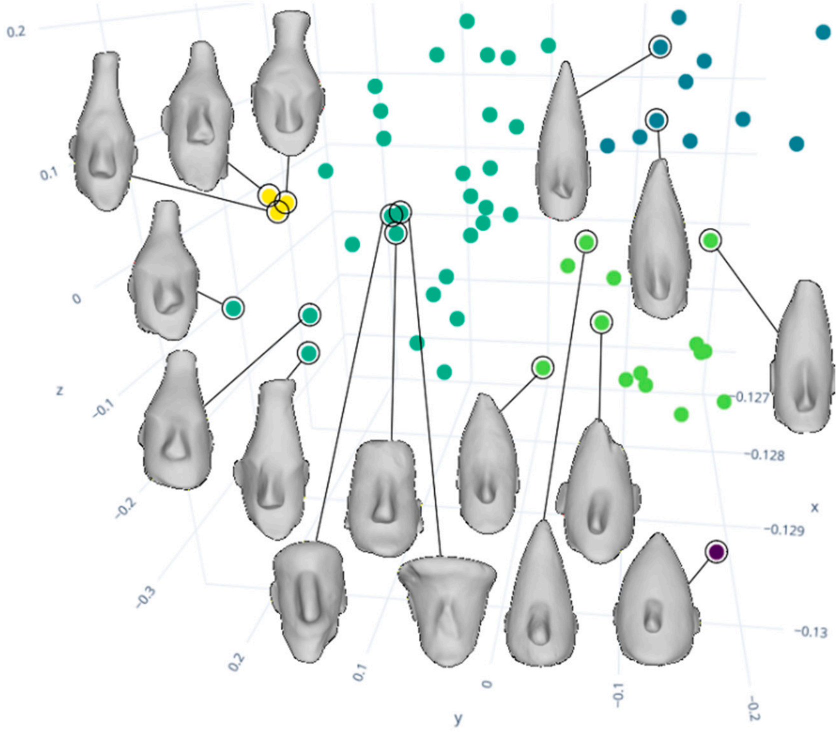

Figure 4.29
Experiment 2. Results of the analysis applying the knn-ε threshold (k = 10) on the handmade heads (Vassallo©).

Experiment 3: Inter-class clustering

The third experiment focuses on the whole Ayia Irini heads sample, consisting of the forty-three moulded and the sixty handmade statuettes' heads. This analysis aimed to testbed the previous experiments and to prove the applied method, first for estimating the correctness of the automatic division of the heads between the two types of production (handmade and moulded) and second to check if any other remarkable groups automatically appear comparing all the dataset items. The unsupervised analysis run with the *knn-ε* threshold (k = 15) (Figure 4.30). The analysis accurately shows the main subdivision of the material into two groups according to their production technique. Figure 4.30 shows the division between the handmade heads (dark green) and the remaining artefacts, characterised by moulded heads. Moreover, as highlighted in the previous analyses, the test on the whole sample confirms the presence within the moulded statuettes group of a further subdivision between the group of the “short hair” (Aegean blue and yellow) and the group of the “long hair” heads (purple, lime, and light green).

Furthermore, the current experiment highpoints the same subdivision identified with the previous tests, confirming two sub-groups within the “long hair” heads. It is important to note that this experiment, to the previous ones, shows a further subdivision (demarcated as outliers) within one of the “long hair” groups: the lime dots separated the heads represented by the purple dots. In contrast, the previous analyses grouped them in the same cluster. As we hypothesised for other groups, there might be various reasons for its state. The test highlighted again an outlier element belonging to the moulded heads group but closer to the handmade heads cluster. The item is again the A.I.1249, and the difference is due to its fallen attached beard, which traces muddle the clustering algorithm. The experiment results on the whole dataset are compliant with the previous ones.

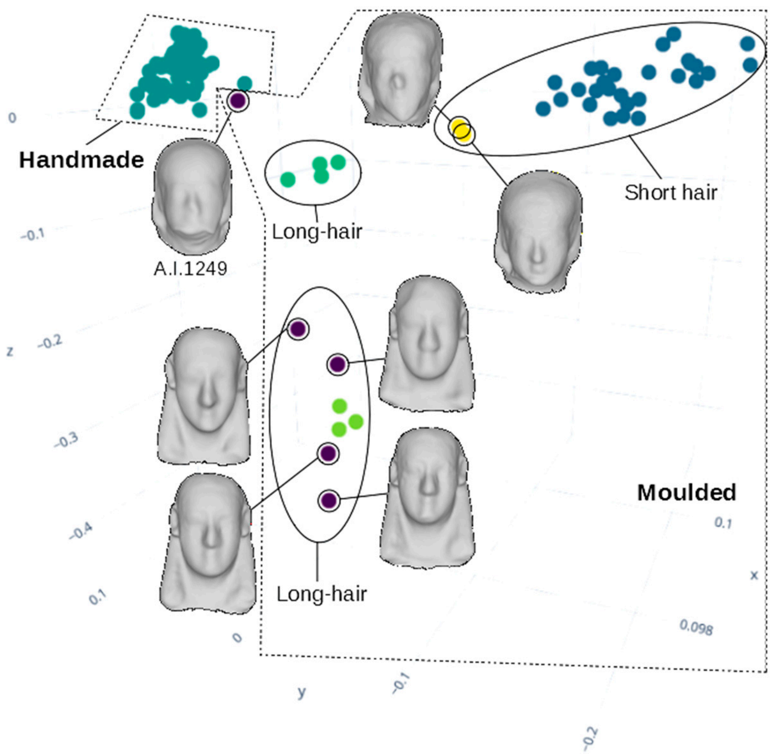

Figure 4.30
Experiment 3. Results of the analysis applying *knn-ε* threshold (k = 15) on the whole dataset (Vassallo©).

The analysis of the heads underlines that the automatic algorithm is powerful if considering the presence of modifications and differences for various reasons. For instance, within the "long hair" clusters, some heads present partly broken or worn-out areas (e.g., A.I.85 and A.I.3893) that do not create issues identifying the similarities.

On the other hand, the algorithm also recognises those differences that might have significance in the similarity clustering. Earlier in this chapter (p. 157), we mentioned how the investigation regards the search for the same characteristics or faults in identifying products made with the same tools and proof of the similarity in coroplastic studies.[219] The algorithm identified the presence of a small hole with a constant dimension of 0.2 cm of diameter in the middle of the heads' top of the figurines attributed to the smaller "long hair" group (A.I.83, A.I.85, A.I.88, and A.I.113), contributing to the similarity clustering (Figure 4.31).

After such identification, I further 3D visualised and analysed all the digital replicas with rendering functions (e.g., the "Radiance Scaling" MeshLab filter). The analysis of the moulded heads highlighted several features, such as working signs possibly due to the different pressure on the clay to create the shape during the moulding process. For instance, among the heads belonging to the smaller "long hair" group, we can notice steep and stark hairlines and slight thickness differences in the render of the lateral part of the hair (Figure 4.32 and Figure 4.33). The 3D analysis also focussed on holistic visualisation in search of common secondary features (e.g., arms, shawls, accessories) that could provide information about the artisan/s attribution. That holistic 3D qualitative comparison of the bodies, together with the measurement previously extracted, identified in this small group the presence of the same position, the same hands' tips and measurements of the arms, and the same way of rendering the shawl with the addition of small clay pieces on the front.

[219] These studies usually rely on manual, linear measurements that are not always enough to understand more complicated manufacturing patterns and bring to misinterpretation and biases.

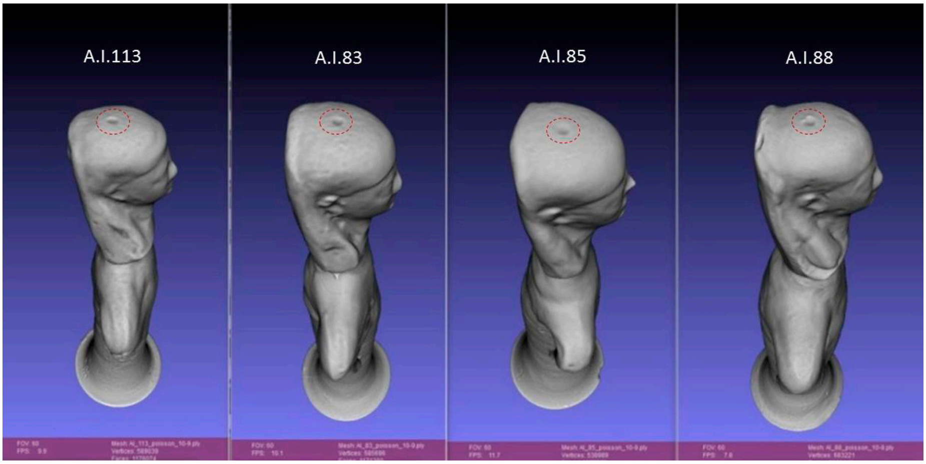

Figure 4.31
3D digital comparison of the holes on the upper part of the heads (Vassallo©).

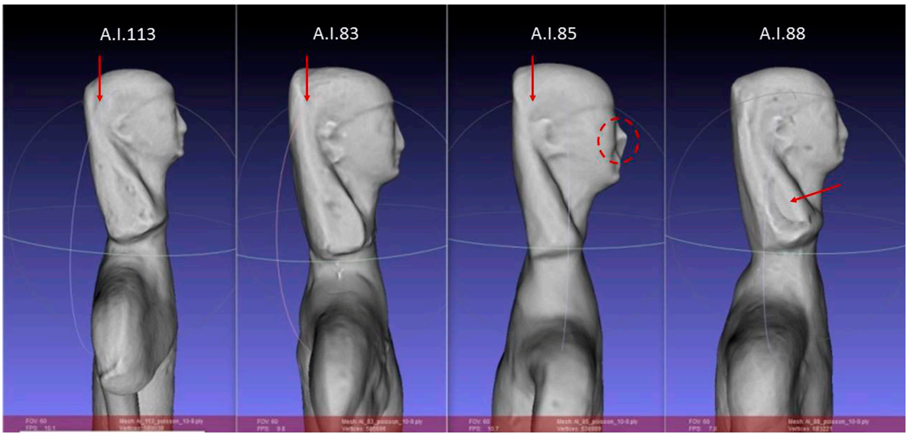

Figure 4.32
Comparison of the lateral part of the hair. The 3D visualisation highlights traces of the single mould and worn-out areas **(**Vassallo©**).**

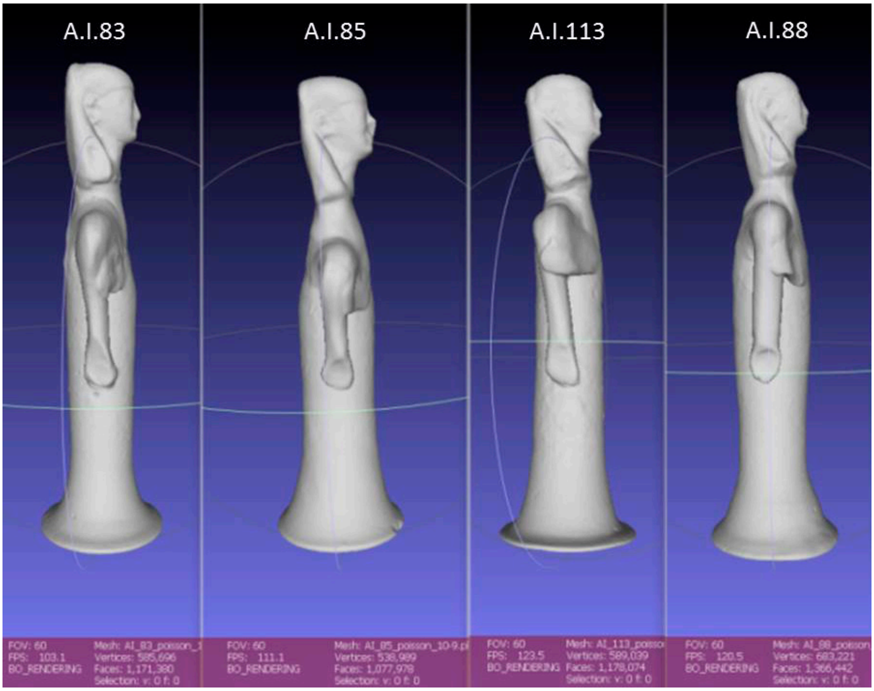

Figure 4.33
Complete lateral view of the statuettes attributed to the same group (Vassallo©).

The digital visualisation filters (e.g., “Radiance Scaling”) applied on the 3D heads comprised in the “long hair” larger group show, instead, more defined features with no significant differences (only the head of the A.I.3893 statuette presents slightly less-defined areas) and does not enhance the steep cast’s line as in the previous case since the impression appears uniform in all the samples (Figure 4.34). The 3D visualisation did not highlight common characteristics or signs on their back parts. Contrarily, it highlighted some qualitative similarities and differences in the figurine’s bodies. For instance, some statuettes (A.I.1507 and A.I.1535) present similar secondary elements similar to the figurines belonging to the “long hair” smaller group (such as the rendering of the arms attached to the trunk, the same rendering of the hands pressed at the tips, and similar shawls covering the front of the torso). The remaining statuettes present different arms than the previous ones, shaped as clay rolls with rounded ends. Nevertheless, they present similarities with the others, either in the shawl rendering (A.I.1499 and A.I.888; A.I.1496, A.I.1507 and A.I.1535) or body shape (A.I.1250 and A.I.3893).

The 3D holistic visualisation highlights the same patterns within the remaining figurines belonging to the ‘short hair’ group, with similarities between those previously mentioned secondary elements. For instance, sub-groups appear with a similar rendering of the arms with hands pressed at the tips and no presence of shawls (A.I.1660, A.I.445, A.I.1205, and A.I.1235). Some figurines share analogous arms shaped as rolls with rounded ends similar to those identified in the ‘long hair’ larger group and similar decorations (e.g., AI 872, AI 876, AI 877, AI 881). Other small sub-groups present secondary qualitative elements, such as accessories (A.I.713, A.I.1128; A.I.1485 and A.I.1871; A.I.109 and A.I.101. Another sub-group appears to be defined by a similar decoration (A.I.102, A.I.245, A.I.92, and A.I.96).

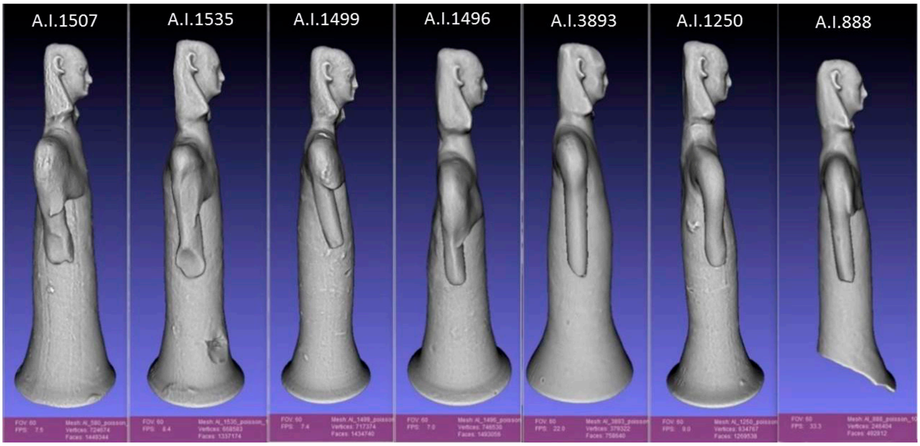

Figure 4.34
3D visual comparison of the ‘long hair’ larger group (Vassallo©).

The analysis run on the handmade heads confirms once again the power of the automatic algorithm for pondering the higher shape variability of these figurines and the changeability due to the manual technique employed for their production.

Beyond the automatic analysis, also for this group, we carried out a holistic qualitative analysis, consisting of the 3D visual assessment of the artefacts and the identification of their variable macro characteristic. In this regard, it has been possible to characterise the handmade statuettes by a range of different features which contributed to their *chaîne opératoire* interpretation.

4.2 Multidisciplinary data integration for the identification of production patterns

Together with shape and size, composition and structure characterise the archaeological artefacts. Therefore, the study of the artefacts, beyond the analysis of manufacturing aspects, should also focus on identifying production patterns, material characterisation, and provenance for creating groups meaningful to their interpretation. The first passage, previously treated, consists of classifying the material according to meaningful groups through 3D shape analysis; the second and current one is the analytical step of identifying objects groups through physical and chemical investigations and possibly evaluating the provenance or origin of the materials used (Buxeda i Garrigós & Madrid i Fernández 2016: 14). Of course, this does not mean there is a necessary correspondence between the archaeological concept of a workshop (or production centre) and the group of artefacts constituted of the same material, but, in general, we should put these two aspects in relation for a better and broader contextual interpretation. For instance, investigating the technique employed for creating a figurine can give precise information on the production background; knowing the object's material composition (e.g., clay, pigment) can often tell where it comes from, suggesting possible social patterns and trade routes. In this context of identifying production patterns through materials properties analysis, non-invasive chemical analysis of the material surface and the polychromy (identification of pigments) play an essential role in the interpretation of archaeological artefacts. The proper identification of pigments may provide useful information for art-historical and archaeological studies on aspects like raw material provenance, production patterns, techniques or workshops' habits, and diachronic developments of style and technique.

Consequently, we conducted a non-invasive physico-chemical investigation of the sample. A summary is provided by the assessment of earlier analytical research on the assemblage.

Clay

The clay analysis is not part of this research since it usually performs a non-invasive chemical analysis.[220] However, we observed the macro

[220] The limitations of the XRF do not allow to analyse the clay in depth, but to get only partial surface information (see Hunt 2016 for different techniques applied to clay analysis within ceramic studies).

characteristics of the artefacts' clay (e.g., colour and texture) to detect similarities and obtain possible hints about their production. The only information available on the clay is from the invasive and non-invasive analysis performed on statues, statuettes, and fragments of the Ayia Irini group conserved at the Medelhavsmuseet (Ikosi 1991-92: 274, 267; Ikosi 1992; Brorsson 2016a: 22-29; Brorsson 2016b; Mühlenbock & Brorsson 2016: 299-311).

Ikosi (1991-92; 1992) performed analytical investigations of the terracotta to identify coroplasts by analysing the techniques and the clay types. She reports two major clay classes: a calcareous one and another rich in volcanic rocks.[221] Both clays were identified as compatible with the geology of Ayia Irini, more generally with the Kormakitis area. Moreover, the presence of foraminifera and inclusions that are compatible with the geological context of the Kormakitis-Astromeritis area characterise the clays analysed, possibly supporting the identification of clay beds in the area for material supplying (Ikosi 1991-92: 267). Ikosi explains that they carried out an initial classification of the clays studying their inclusions through a magnifying glass (magnification 30x) and with reference charts for what concerns the estimation of inclusions percentage. The aim was to identify the main clay types based on which a further selection of a sample for a petrographic analysis could have been done (Ikosi 1992: 36-37).

The results of the visual description indicate three main clay types (Type A, B, and C). Not all the items could associate with the defined types, but they classified most of the material observed with clay Type A, and then in lesser percentage with Type B and C. The conclusion made by Ikosi is that groups sharing the same clay correspond partly to the same coroplasts (Ikosi 1992: 36-37). The visual observation of inclusions was in line with the subsequent petrographic analysis. They performed thin sections on Type A, B, and C samples that revealed their foraminiferous character: Type A and B of a calcareous matrix (presence of quartz, mica, hematite, plagioclase feldspar, hornblende, and epidote) and Type C with volcanic characteristics and components of minerals sanidine, pyroxene and hornblende (Ikosi 1992: 82). Ikosi states that on the base of the clay type, the choice and the

[221] The analyses were carried out by Josef Riederer for what concerns the petrographic analysis and Hans Georg Lindenberg for the inclusions. Another result of petrographic analysis carried out by Riederer on material coming from the Kythrea temenos in Cyprus underlines the presence of calcareous clay, again similar to the Ayia Irini ones (Ikosi1993). Moreover, the clay analysis carried out by Svärdh (Ikosi 1993) on some terracotta figurines from the Kythrea temenos confirmed the use of highly calcareous clays for the preparation of the artefact's bodies.

morphology of the technique used, the style and the iconography details, it is possible to identify different coroplasts, and in particular, at least two masters that led the production of the terracottas of all different sizes (Ikosi 1991-92: 274). Unfortunately, beyond providing a chart table on the two types of clay used for 154 medium size terracottas (Ikosi 1991-92: 307) and the identification of two masters on the observation of 1293 terracottas (1991-92: 308), she does not transparently explain how reached that conclusion and which are the artefacts considered to arrive at that deduction.[222]

The recent work conducted by Christian Mühlenbock and Torbjörn Brorsson (Brorsson 2016a: 22-29; Brorsson 2016b; Mühlenbock & Brorsson 2016: 299-311) aimed at examining the compositional similarity or variability of the clay of the items sampled at the Medelhavsmuseet to determine possible technological and compositional patterns. The researchers compared the results with past typo-chronological studies (Gjerstad et al. 1935; Fourrier 2007). In this case, the primary (invasive) method of analysis applied to the sample for its chemical characterisation was the Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). The sample consisted of different objects: 50 samples from terracotta statues, statuettes, and figurines (corresponding to the Gjerstad "large human idols" and "small human idols"), entire or fragmented, and 17 samples from pottery sherds. The non-organic elements identified and statistically processed brought to the determination of eight sub-groups. The observation of these subdivisions made possible some conclusions. The first is that all items, comprised in a period between Late Bronze Age and Cypro-Archaic II (from 1450 BC to 475 BC.), reveal a similar chemical composition that makes researchers believe of the same geographical area of provenance for the clay. Unfortunately, there is no comparative study to obtain information about the exact supply area.[223]

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[222] Ikosi provides a successive description in 1992, but the scholar mentions 101 items consisting of unpublished terracottas and represented by mixed types, such as large statuettes, chariots, and small figurines. In that case, she partially associates the items to the type of clay.

[223] The two scholars identified also some artefacts, chronologically posterior, characterised by a different clay composition that might suggest a different geographic provenance (see Chapter 5).

Slip

Ikosi (1992: 36) provides information about the slip[224] only after visual observation of the clay thin sections. Ikosi identifies the presence of a thin wash layer on the exterior or both on the exterior and the interior of the items selected, most probably resulting from immersion in a bath of diluted clay. This approach brought a non-systematic identification of the slip on the samples, often due to the lack of clear colour contrast between the terracotta and the coat (e.g., use of the same-colour clay for both the parts). In some cases, clean cracks in the material helped to identify the different layers. According to the Munsell system[225], the clay and the slip's general and most frequent colour is 2.5 YR 6/6.

Pigments[226]

There are few previous scientific analyses to characterise the pigments.[227] Ikosi (1992: 36, 39) provides only indirect information about paint and

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[224] According to Walters (1903: xxiv), artisans usually applied to figures a layer of clay slip or white englobe (pigment constituted of white lead kaolinite, or calcite). This coat served to render the figure waterproof and enhance its surface by eliminating porosity or clay imperfections and providing a homogeneous base for the decoration (Cuomo di Caprio 2007: 305). From an analysis of some material coming from different locations and geographical areas and conserved at the British Museum, it seems that this kind of white coat was widely present and applied after firing. The after-firing procedure is quite sure for what concerns kaolinite application since temperatures above about 500° Celsius affect its integrity. The successive step consisted of the possible application of decorations with coloured pigments (see Burn & Higgins 2001: 18–20, Appendix 2; Brinkmann 2008: 18-39).

[225] *Munsell soil color charts* (1992). Newburgh (New York: Macbeth). http://munsell.com/

[226] For a wider view on the topic, see Shepard (1956: 31-44) for all range of paints available to ancient potters and Jones (1986: 798-805) for a review of ancient pigments' analytical data.

[227] It is here underlined that Aloupi & McArthur (1995) wrongly attribute the results of the clay and pigments analysed by Ikosi (1993) to the Ayia Irini material. In reality, those investigations refer to the analyses of some terracotta figurines of the 6th century from the Kythrea temenos (see note 221, p. 194), for which the presence of Mn-rich dark and iron clay-based materials for the red pigments is reported. Nevertheless, also Aloupi & MacArthur (1995: 145-155) report about the presence of pigments used for decoration on other Cypriot material during the Archaic I-II periods, showing the use of the so-called Manganese black technique applied on top of the surface of the artefacts before firing. According to Aloupi & MacArthur (1995), the employment of the technique seems to be used during the cited period in Cyprus respect to mainland Greece, where artisans already abandoned the technique and they replaced it with the iron reduction technique (the topic is also treated in Karageorghis et al. 1997:4-7 for what concerns black and other pigments used in Cyprus).

colours. The scholar suggests matte colours (black and red) for her sample. The employment of iron oxide pigments is an assumption based on X-ray diffraction analysis carried out on other terracottas from the site (unfortunately, she does not provide further information about which items she refers to). The analysis of that secondary material proved the presence of haematite for red pigment and maghemite or magnetite for black (Ikosi 1992: 36, 82). She visually analysed the colours (clay, slip, and pigments) with the Munsell system under artificial light. Ikosi states that their reading is approximate for the black pigments since, in most cases, only a few traces survived (Ikosi 1992: 39).

According to the sources (Lucian, Lexiphanes, 22)[228], ancient statuettes were decorated with bright pigments, but there is currently very little evidence (Walters 1903: xxiv).

Most Ayia Irini statuettes present only remains of slip or pigment. This lack could be because these objects did not present any decoration either because when drying, the slip drops off, most probably carrying the decoration with it. Alternatively, poor conservation caused the problems. In the past, the *SCE* workers cleaned the statuettes with deep washes.[229] For these reasons, most show only the coating, traces of that, decoration residues, or a combination of the two. The descriptions by Gjerstad et al. (1935), in some cases, report the presence of decoration (more or less evident); others do not.[230]

Similarly, in her study on the dresses and armours of the Ayia Irini figures, Törnkvist proposes that most colours disappeared over time. In the 1970s, the scholar reports that mostly red and black, with variances from brown to bluish or violet, are visible; the small statuettes also present a light brown slip, mostly on reddish terracotta. Moreover, referring both to the so-called larger and small idols, Törnkvist reports the presence of black colour remains on details like helmets, beards, lower borders, and mantles. According to

[228] '[…] ὡς νῦν γε ἐλελήθεις σαυτὸν τοῖς ὑπὸ τῶν κοροπλάθων εἰς τὴν ἀγορὰν πλαττομένοις ἐοικώς, κεχρωσμένος μὲν τῇ μίλτῳ καὶ τῷ κυανῷ, τὸ δ᾽ ἔνδοθεν πήλινός τε καὶ εὔθρυπτος ὤν'. You are like the small figures of the coroplasts at the market, painted with red and dark blue outside, and of fragile clay (Lucian 1979).

[229] Ikosi (1993:79, note 76) reports that Alfred Westholm, in personal communication, informs them that they used acid for cleaning the artefacts. Although it is not clear if they refer to specific artefacts, maybe that was a standard procedure adopted by the Cyprus Swedish Expedition in cleaning the excavated material.

[230] Concerning the material conserved at the Cyprus Museum, there is also a dis-alignment between the literature description and the one in the museum's digital catalogue (see the Catalogue appended to Chapter 2 where the differences are highlighted).

Törnkvist, artisans applied colours on the statuettes as ornamental patterns without a specific function during the earlier periods and, if any, with ritual meaning. The author justifies this idea because also animal figures present similar decorative patterns[231]. Specifically, she states: 'On many of the small idols, the painted lines are probably mere decorations for the idols seen as idols, rather than illustrating a real chiton pattern […]. But on the larger statues, it is otherwise' (Törnkvist 1970:111; Törnkvist 1972-73: 51-52). Usually, apart from some exceptions, the backs are unpainted (and also not smoothed), hinting that they should not be seen from the front side and were created only for that specific aim.

Beyond the latter, no in-depth studies focused on the decoration type of the sampled statuettes. The observation of the selected statuettes brought to the identification and standardisation of a series of patterns, and their associated colours, which we named partly on the archaeologists' definitions (Gjerstad et al. 1935, Karageorghis 1995) and partly developed within this research (see partonomy in Chapter 3): e.g., groups of parallel lines and bands (black), radial patterns (black, or association of black and red), 'V' patterns (black, or association of black and red), lozenges patterns (black), and ladder-patterns[232] (black). We also named 'generic area' some coloured zones identified on the statuettes (Figure 4.35). Identifying the type of decorations and the related colours is useful within the research methodology, so patterns can be associated with other classification parameters.[233]

[231] Sjöqvist (1933: 335) suggests that those decorations might be a reminiscence of cult clothes put on the animals. Karageorghis (Karageorghis 1995: x) provides some comments on decorations, not specifically addressed to the Ayia Irini material. As mentioned in Chapter 1, the archaeologist suggests that the Cypriot terracotta figurines of the Cypro-Archaic I and II (ca. 750-475 BC) were most probably created on the island, maybe in potteries' workshops, together with the production of vases. As a support to this affirmation, he brings the fact that, during that period, the artisans decorated the material with abstract motifs and in black and red, following the same style of the vases of the same period (e.g., Bichrome IV ware style -see Chapter 1, footnote 10, p.14). Nevertheless, as suggested by Karageorghis, this does not exclude the presence of individual coroplasts working on their own, as the presence of different decorations or of figurines that were not painted at all could suggest. In general, polychromy appears more often on clay figurines than on vases; and in some places there are samples (e.g., in Kourion) where artisans applied a white undercoat used as a base for the decoration (Karageorghis 1995). The coating technique may derive from the Greek coroplastic art and, as well as in Greece, in Cyprus during the 600-550 BC the potter crafting and the coroplastic art were separated (Higgins 1954: 68-70).

[232] As in Gjerstad et al. 1935, the name of this pattern comes from the fact that two vertical parallel lines intersected by small parallel horizontal lines create a ladder's shape.

[233] The geometric information (e.g., 3D information, topological analysis) and the analytical data (non-invasive chemical analysis of the polychromy through XRF technique and

In this context, the close visual observation of the artefacts and their 3D digital counterparts, the review of previous analytical investigations results, and the archaeological literature allowed the identification, beyond the presence of black and red, of yellow traces and decorations (yellow associated with red and black) which were not mentioned or described in any of the past publications.

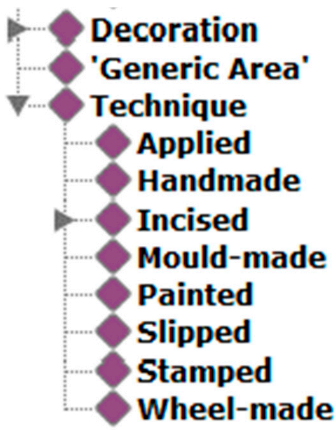


Figure 4.35
Partonomy section related to Decoration (Vassallo©).

The visual identification of ‘new’ colours’ traces raised several archaeological questions:

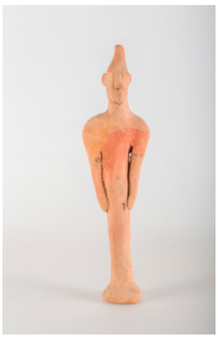
- Are the identified traces of pigments? If yes, what kind of pigments, in terms of chemical composition? Are these pigments part of a decoration, or are they due to contact/proximity with other decorated artefacts?
- Regarding the yellow’s identification, is that colour usually more faded and therefore not visible to the naked eye? Is yellow always associated with black and red?
- Is slip always present? Does slip exist only on decorated items?

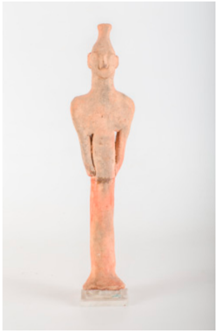
microscope) will be supported. Thanks to the partonomy support, in the feature it will be possible to compare patterns and identify similarities in terms of shape/geometry and chemical composition of the pigments constituting them (Catalano et al. 2020).

- Moreover, for identifying production patterns and provenance of the small statuettes aimed at classification: Can yellow (or a pattern) be associated with a specific type?
- Consequently, can specific decorations and pigments inform us about the production by the same artisans/workshops and provenance?

Table 4.5 documents the visual examination performed on the Ayia Irini statuettes conserved at the Cyprus Museum and sampled for this research. These figurines are the only six items belonging to the CM sample, which, after the visual analysis, showed other traces of colours beyond the black one. Therefore, the number of figurines is sufficient to analyse and respond to the research questions. The column titled "Comments" documents the visual examination, the literature review and the research questions specifically related to each artefact (for general information on the item, see the Catalogue).

Table 4.5
Statuettes analysed with XRF because of the possible presence of pigments identified after the visual examination.

ID	INV. NO.	IMAGE	COMMENTS
33	A.I.349		The A.I.349 figurine presents a possible decoration composed of three colours: a red area on the left shoulder and a large, undefined, faded yellow area on the right shoulder. Traces of red are also visible on the back of the head, and black lines are visible on the arms. Gjerstad et al. (1935: 686) do not mention the presence of any colour or decoration (the only reference is the similarity with the statuette A.I.145, for which, nevertheless, they only cite the presence of black on beard and helmet). <u>Questions</u>: Can we attribute the faded coloured area to yellow? If yes, is the yellow colour due to a pigment application? Are the yellow traces related to a specifically planned decoration? Is the presence of that colour due to contact with other coloured artefacts? If they are colour traces, what kinds of pigments do they use? Can the composition of the pigments give us information about the production and provenance of the artefact?

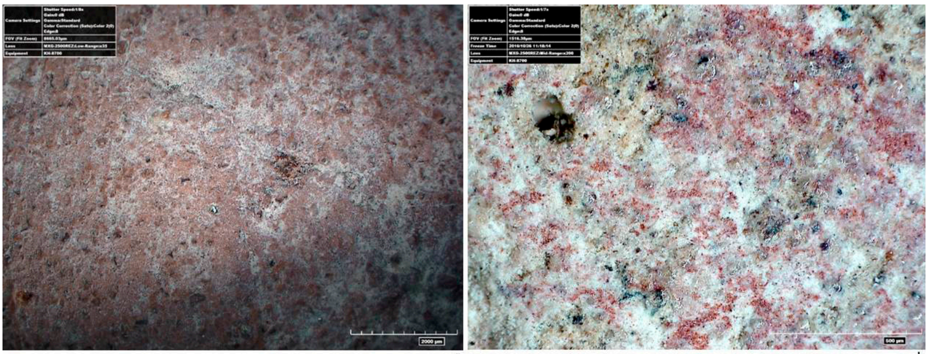
ID	INV. NO.	IMAGE	COMMENTS
31	A.I.321		After a preliminary visual observation was not clear if the A.I.321 figurine presents colours, it seems to have a red area on the lower part of the body and a black one on the top. In Gjerstad et al. (1935: 685), there is no information about the presence of colours (the only reference is the similarity with the statuette A.I.145, for which, nevertheless, they only report traces of black on beard and helmet). Questions: Due to the resemblance of the shape with the A.I.349 figurine, could the A.I.321 statuette present similar colour traces and decoration (red, black and yellow)? If yes, what kinds of pigments do they use? Can the composition of the pigments give us information about the production and provenance of the artefact? Is the dark colour on the top part due to the use of pigment, or has an organic composition?
35	A.I.405		Large traces of black on the back and red on the front. Gjerstad et al. (1935: 687) report on the presence of red slip, partly darkened by soot. Questions: The A.I.405 figurine resembles the A.I.349. Did they have the same decoration (red, black and yellow)? Are the dark traces due to a burn? Are the red traces due to slip?
21	A.I.111		Visible traces of black and red pigments creating a geometric decoration ("V" pattern) are visible. Gjerstad et al. (1935: 679) report various red and black traces for decorating the figurine. Questions: Beyond the presence of black and red pigments, are there traces of other colours (e.g., yellow) not visible to the naked eye? Is there a specific association of colours on certain figurine types?

ID	INV. NO.	IMAGE	COMMENTS
29	A.I.245		The presence of details and visible traces of black and red pigments create geometric decoration (e.g., radial pattern, "V" pattern, group of lines, band). Gjerstad et al. (1935: 682) reports traces of black and red and black decoration and black details. <u>Questions</u>: Beyond the presence of black and red pigments, are there traces of other colours (e.g., yellow) not visible to the naked eye? Is there a specific association of colours on certain figurine types?
39	A.I.816		Identification of colour traces on the A.I.816 figurine: red traces on the headband and the dress; few traces of possible yellow seem to be visible on the right ear and the face. Gjerstad et al. (1935: 697) mention the presence of red colour on ears and headband, black on eyes, eyebrows and mouth-band, and some traces of black on the body. <u>Questions</u>: Are the traces of yellow attributable to pigment? If yes, are specific planned decorations due to contact with other coloured artefacts? What kinds of pigments are they? Can the composition of the pigments give us information about the production and provenance of the artefact?

After the visual observation, verifying the characteristics qualitatively with scientific and quantitative analysis is necessary. We operated a non-destructive analysis under ultraviolet light (UV) for an initial diagnostic examination. This kind of qualitative analysis is useful to identify, for example, restored areas (e.g., surface inconsistencies of the objects, glues, repairs, fills) or organic dyes (Hickey-Friedman 2002:163; Gasanova et al. 2018: 86, 87). Consequently, we performed a digital microscopy analysis with the Hirox KH-8700 on the six (A.I.349, A.I.321, A.I.405, A.I.111, A.I.245, and A.I.816). We photographed selected spots at various magnifications (×35–×2500) to detect possible pigment traces' and study their particles' appearance. At this first stage, the investigation confirmed the unambiguous presence of pigments' traces for almost the totality of the sampled artefacts.[234]

Nevertheless, the results obtained by the microscopy investigation have to be quantitatively confirmed by further digital analysis. The next part of the study focuses on the polychromy's characterisation of the traces identified on the sampled Ayia Irini statuettes conserved in Cyprus. Particularly, a characterisation of the figurines was fundamental to identifying the pigments used for the small figurines' decoration and their production patterns. Moreover, none carried out physico-chemical analyses, invasive or non-invasive, on any specimen of the Cyprus Museum group; therefore, this kind of analysis is highly useful to the current research aims. Then, we analysed the traces of pigments previously detected with microscopy with the ARTAX-200 μXRF spectrometer for X-Ray Fluorescence Spectroscopy (XRF) to obtain their chemical composition (see Chapter 3 for technical specifications and parameters). We analysed several spots of the statuettes' bodies: the figurines' analytical mapping was to cover the colours (visible and slightly visible) and their representative parts.

Finally, we employed 3D visualisation renderings (e.g., Meshlab filters) to compare similar figurines, as previously clustered by the shape analysis and which did not go under physico-chemical investigation, to find further common features useful to the classification and interpretation



a b

Figure 4.36
Micrographs from A.I.405 (a) and A.I.816 (b) red areas. The comparison shows the difference between the absence (a) and the presence (b) of pigment. (Vassallo and Gasanova©)

[234] The digital microscope was extremely helpful for the examination of the figurines and for detecting traces connected with the production, particularly of the decoration's activities.

Pigment analysis results

Red

All the selected figurines have red areas detectable to the naked eye. More in detail, close microscopy observations suggested that some of the red areas of A.I.321 and A.I.405 (and some of A.I.111) are not due to a red pigment but the reddish colour of the clay body (Figure 4.36a). Further XRF analysis confirmed this observation as the XRF spectra, taken from the red areas and the clay body did not differ in the number of elements detected or in the intensity of XRF lines. In the case of the remaining red areas of A.I.111, A.I.321 and A.I.405, and A.I.816, microscopy observations allowed to detection of traces of a red pigment with dark-red, fine, opaque particles. The analysis characterised the red pigment of A.I.349, A.I.816, and A.I.245 as red ochre (Fe2O3+clay).

Figure 4.39d shows XRF spectra taken from the red area of A.I.349 and its clay body. The higher intensity of Fe lines in the spectrum of the red pigment indicates iron-red pigment. The presence or absence of Si and Al in iron-red pigments applied on terracotta artefacts can hardly serve as the marker of red ochre as Si, and Al lines in the XRF spectrum are also due to aluminosilicates of the clay body. The conclusion on red ochre in the case of A.I.349 and A.I.816 relies on the presence of Ni and Mn lines in the red pigment's XRF spectrum and the slightly higher intensity of Cu and Cr lines.

XRF analysis did not detect any Hg on the red spots, which allows for excluding cinnabar (HgS), a more precious and expensive than ochre red pigment used in antiquity. XRF data also exclude the possible admixtures of red lead (Pb3O4) or realgar (As4S4). The UV survey did not show any evidence of madder lake; thus, red ochre was the sole red pigment used on the selected figurines.

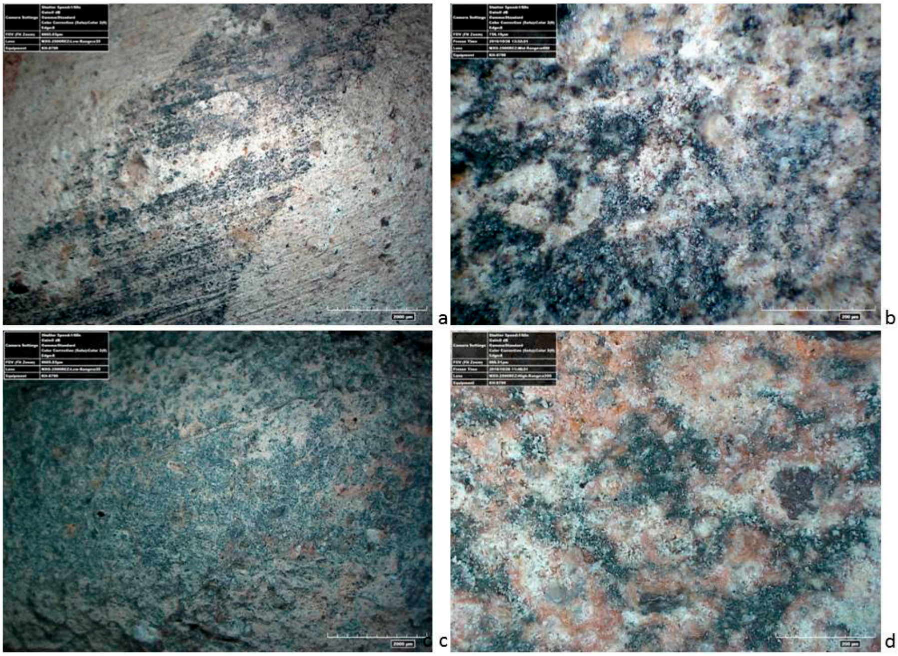


Figure 4.37
Micrographs from black areas of: A.I.111 (a, b) and A.I.405 (c, d). (Vassallo and Gasanova©)

Black

The visual examination of all selected figurines determined the presence of black colour. The microscopy observations confirmed a black pigment application on A.I.111, A.I.245, A.I.349, and A.I.816 (Figure 4.37a, b). The pigment particles are fine to coarse with an irregular shape. XRF spectra of the black areas show intense Mn lines pointing at a black manganese pigment such as MnO2.

In contrast to these objects, the black areas on A.I.321 and A.I.405 do not have strict borders, complicating the decorative pattern's reconstruction. The black particles in these areas have an exceptionally fine size. Moreover, the black colour can be seen not on the surface but absorbed by the surface layer (Figure 4.37c, d). XRF spectra taken from the clay body of A.I.321 and A.I.405 and the black areas do not show any difference in Mn or Fe lines suggesting the black colour's organic origin. The latter could indicate the presence of carbon black pigments such as soot, charcoal, or ivory black. However, the microscopy observations and the XRF results suggest that the black colour on A.I.321 and A.I.405 is not due to a black pigment but to contamination.

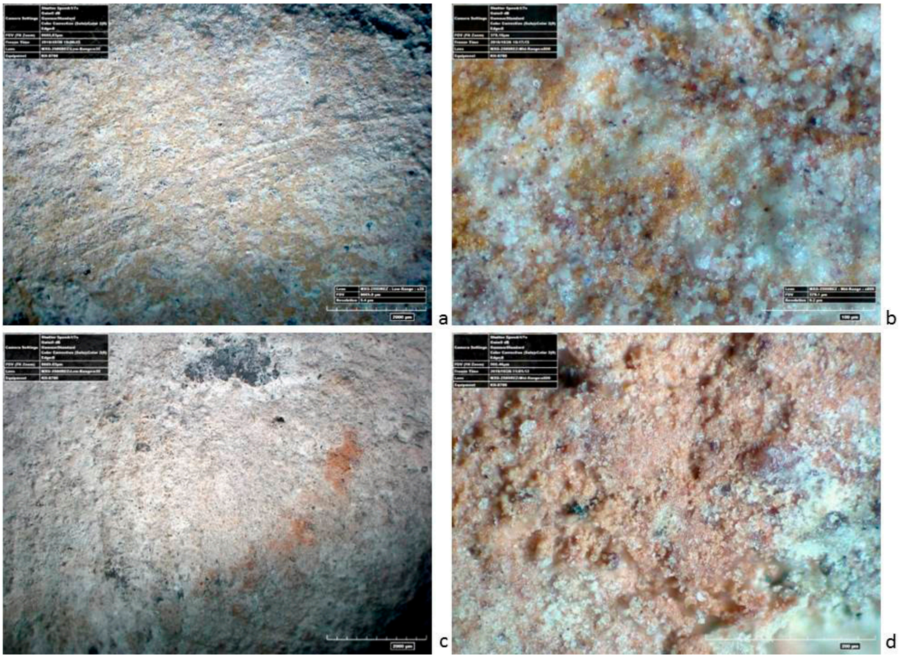


Figure 4.38
Micrographs were taken from yellow areas of: A.I.349 (a, b) and A.I.816 (c, d) (Vassallo and Gasanova©)

Yellow

The close visual examination of the figurines suggested the presence of a yellow decoration, previously unknown, on A.I.349. The subsequent microscopy analysis confirmed this assumption and allowed the detection of the yellow colour on A.I.321 and A.I.816, both not reported in the literature. The latter has an orange hue and unrecognizable pigment particles (Figure 4.38c, d). Compared to A.I.816, the yellow pigment on A.I.349 preserved better. Figure 4.38c, d shows large areas of pale, sandy yellow colour with opaque particles of up to 5 μm. The yellow pigment particles on A.I.321 are similar to A.I.349, but in this case, a very small amount of colour survives.

The XRF analysis results suggest that the yellow pigments on A.I.321, A.I.349, and A.I.816 have different chemical compositions. In the case of A.I.349, the XRF spectrum of the yellow pigment has a higher intensity of Fe, Mn, and Cu lines than the one of the clay body suggesting yellow ochre

(FeO(OH)+clay) (figure 4.39a). The comparison of XRF spectra of the yellow pigment and the clay body in the case of A.I.321 (figure 27(b)) indicates iron sulphate such as jarosite (KFe3(OH)6(SO4)2) or natrojarosite (NaFe3(OH)6(SO4)2) due to the presence of S lines. The XRF spectrum of the yellow pigment of A.I.816 (figure 4.39c) does not show the higher intensity of Fe lines that exclude iron yellow. Instead, the spectrum shows two As lines at 10.54 and 11.72 keV pointing out at orpiment (As2S3).

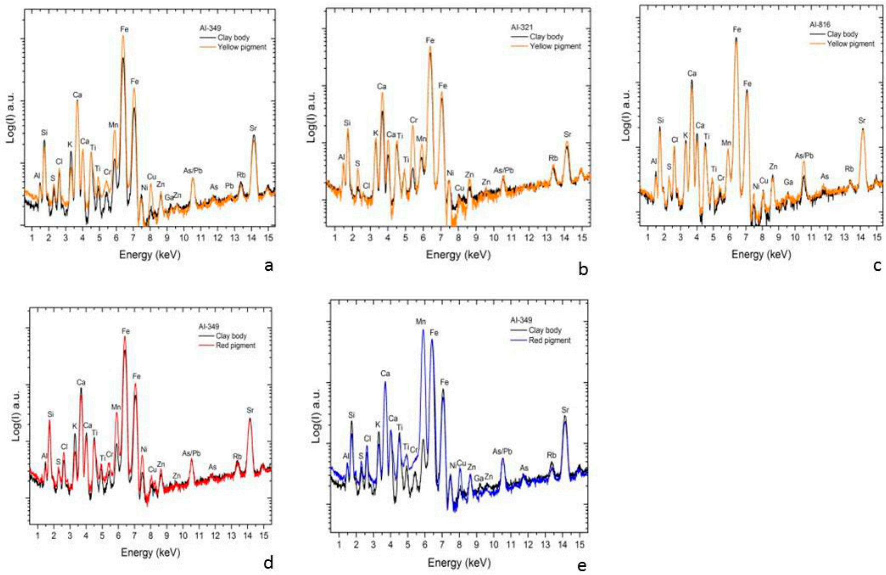


Figure 4.39
XRF analysis of painted decoration: yellow pigment on A.I.349 (a); yellow pigment on AI-321 (b); yellow pigment on A.I.816 (c); red pigment on A.I.349 (d) and black pigment on A.I.816 (e). (Vassallo and Gasanova©)

4.3 Digital re-contextualisation of the figurines in a 3D GIS environment

Once we identified the criteria resulting from the geometric and analytical descriptors, we used them to create artefacts' classes, which we have to confront with each other and within their chrono-spatial context. Digital spatial re-contextualisation is important in interpreting small figurines production. Indeed, such a step is useful to explain the figurines' productive chain (*chaîne opératoire*) and further support the identification of common manufactures (e.g., individual hand or more hands attributable to the same workshop) through the analysis of the spatial distribution of the figurines' groups resulting from the geometric and analytical analyses and their temporal relations.

Such a step has a twofold benefit: the chrono-spatial contextualisation of the figurines' techno-typological clusters resulting from the 3D digital and analytical approach helps to understand the function, the social role and the ritual significance of the Ayia Irini sanctuary, as well as the dynamics that occurred in and outside it. Translating this concept into specific research questions:

- What is the contribution that 3D spatial analysis can provide to the definition of new strategies for classifying archaeological material?
- Is it possible to enhance the site and the past archaeological excavation through 3D spatial analysis?

In Chapter 1, I explained how coroplastic studies have profoundly changed their approach in recent years, and such change also produced rapid development in the field. Research, previously focused on artefacts (e.g., style), has moved to an investigation that includes their context, function, production and materials.[235] More recently, the approach involves all aspects (e.g., social, economic, religious, spatio-temporal, political) that could be important or meaningful for interpreting this specific material. Therefore, studying such artefacts without their archaeological context is impossible.

This approach is straightforward if applied to contemporaneous excavations, where the digging process is ongoing, and it is possible to follow their documentation, analysis, and interpretation step by step. The situation is more complicated in past excavations where digging is finished, finds are out of context, stratigraphy destroyed, and interpretations have been published. All that is left is the documentation, more or less accurate since done with traditional methods, and the interpretation of the archaeologist who excavated (with possible lacks and misunderstanding for the same reason as before).

Furthermore, until a few years ago, there was still a reluctance to assess the work done in past excavations and possible stratigraphy inconsistencies. Maybe this was due to a reverent admiration towards the giants of

[235] The analysis of the materials ranges from study of the sources, provenance to distribution.

archaeology and their discoveries or because stratigraphy assumed a fundamental and central role (Harris 1978; "the most fundamental of archaeology's field methods", as Maca 2009: 31 calls it) that has not to be questioned, despite its possible misinterpretations by those archaeologists (quoting Mills 2009: 38, "Archaeologists often take stratigraphy for granted").[236] Moreover, as constantly repeated by archaeologists, any excavation is a destructive process (Lucas 2001: 35).[237] Therefore, it would be impossible to reproduce the past original situation in reality.

Digital re-assessment and digital spatial analysis of past excavations' stratigraphy and material can solve those issues.[238] In this vein, digital datasets can encourage reflexivity in the interpretation process since they permit a more straightforward correlation between the data and re-assessment and integration of sparse information of the excavation archive, subjected to further fragmentation during the post-excavation study (Katsianis et al. 2008: 655, 657: Jones 2001). Such a process allows for managing a large amount of data facilitating a holistic visualisation in the reconstruction and re-analysis of the context, structures, and artefacts, simulating the steps that occurred during the excavation, and visualising things not seen before.

Several recent research projects were devoted to re-examining past excavations: they consented to a re-evaluation of their documentation and material or brought forth discoveries. The need for digitizing legacy data and the possibility of re-evaluating such data with digital technologies promoted such a boost (De Felice & Fratta 2016; Haggis & Antonaccio 2015). The

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[236] It is important to remember that archaeological stratigraphy's interpretation is never impartial, and this is undoubtedly something that starts at the trowel's edge (Helwing 2009:31). The interpretation might begin even before the excavation: what an archaeologist sees in the data depends on what he/she asked for that data (Hodder & Berggren 2003). For this reason, McAnany & Hodder (2009) highlight that stratigraphy should be a reflexive tool that archaeologists should not delegate or postpone after the excavation, but it should work throughout the procedure.

[237] An excavation is a sort of archive that documents the approach and interpretation of an archaeologist. For example, Roosvelt et al. (2015) argue that the excavation shifts the record from objective to subjective.

[238] Beyond the advance already given by the New Archaeology in this direction, to support this re-assessing approach, a few years ago, the CAA International inaugurated the Recycle Award to promote the re-evaluation of legacy data employing digital technologies (https://caa-international.org/bursaries/recycle-award/). One of the issues identified by Stefania Merlo some years ago and partly still valid, is the focus on technical issues rather than on the implications of using digital technologies in archaeology. The author explores how the influence of such technology (particularly of three-dimensional GIS at intra-site level) has –and should have- an impact on our perception of the archaeological record (Merlo 2004).

combined use of 3D modelling and mixed 2.5/3D analysis, archive data, old drawings, maps, and photos shed new light onto past excavations and allowed the identification of new elements. For example, digital spatial tools allowed us to acknowledge new interpretation features that the archaeologists did not record and publish because they did not understand them or details were not visible due to limitations -or the absence- of past technologies. In some cases, researchers spotted several inconsistencies, especially in excavations of the 20th century, at the beginning of the application of the stratigraphic method in archaeology (Landeschi et al. 2018; Houby-Nielsen 2016). In other cases, scholars identified issues of accuracy (e.g., measures, exact positions) in past studies because of the use of manual instruments that produced documentation affected by human errors (Vassallo et al. 2006: 424).

In particular, the new possibilities brought by Geographical Information Systems (GIS) and 3D encouraged many fruitful projects in archaeology and Cultural Heritage.[239] Researchers employed 3D GIS systems to manage archaeological data better and address issues regarding storing, retrieving and eventually analysing them (Jensen 2018; Katsianis et al. 2008). The chance to develop work pipelines that allow the archaeologists to import into GIS conspicuous amounts of 3D data, characterised by complex and texturised geometries, considerably changed the research approach both in the field and in the lab (Landeschi et al. 2015). During the last years, the use of 3D GIS supported and enhanced several research lines, bringing new light to the archaeological discussion (Bezzi et al. 2006; Lieberwirth 2008; Shen et al. 2013). There is a necessity in such projects to document and analyse sites and artefacts with different scopes. Poggi (2016), in his contribution, presents a documentation workflow aimed at the analysis of ongoing archaeological excavations through the use of image-based 3D modelling techniques. Monitoring, preservation, and restoration aims are the main topics of further research: Landeschi et al. (2016) discuss the possibility of assessing the damage to archaeological sites through the combination of image-based 3D modelling techniques and GIS, while Campanaro et al. (2016) propose 3D GIS as processing knowledge tool for cultural heritage monitoring, restoration and therefore preservation. Finally, Piccoli (2016) deepened the analytical and interpretative part: she suggests enhancing GIS with a 3D procedural modelling approach for ancient urban interpretation. Landeschi et

[239] Nevertheless, if, on the one hand, the spatial analysis provided new insights in cultural heritage management and facilitated the critical discussion, on the other hand, it also underlined its limitations (Foka et al. 2020: 3). For instance, one of the concerns in using GIS in archaeology is the possibility of losing the human subjective interpretation in favour of data ‘objectivity’ (Landeschi 2018).

al. (2016) and Richards-Rissetto (2017) both propose 3D GIS as a platform for visual analysis in different case studies and Dell'Unto et al. (2017) put forward the use of 3D GIS as simulation platforms for supporting field interpretation.

The current study fits in this research frame. I used 3D GIS to digitally re-assess the Ayia Irini excavation by corroborating published material and data extracted from the original excavation archive. In this digital space, I compared the traditional classification and the new one obtained through 3D digital, analytical and semantics integration.

As explained in Chapter 2 concerning the site, I identified some issues after analysing the Ayia Irini excavation's documentation and earlier scholarships. From 1927 to 1931, the SCE conducted excavations of archaeological sites (21) throughout Cyprus. Due to the number of sites and the small number of archaeologists, the SCE assigned works to multiple field sites. At Ayia Irini, Sjöqvist excavated, Lindros made drawings, and Gjerstad published the findings.

The following list shortly resumes the identified issues:

- The first issue, already highlighted by other scholars, is that the *SCE* leader, Gjerstad, and not the archaeologist who excavated the site, Sjöqvist, published Ayia Irini's excavation. That situation could cause some inconsistencies in the interpretation of the site.
- The SCE published the official results of the Ayia Irini excavation in 1935, almost six years later. Gjerstad published some revisions and additions to the results in 1948 and 1963 (Gjerstad et al. 1935; Gjerstad 1948; Gjerstad 1963), but they are more about the material than about the site.
- In 1933 Sjöqvist published the first text mentioning Ayia Irini, different from those already cited (Sjöqvist 1933).
- Different opinions regarding the "floods" stratigraphy arise from the publications of Sjöqvist and Gjerstad: they respectively talk about two and four flooding events.
- Additionally, it is possible to identify some inconsistencies between the published and unpublished documentation: for example, the architect Lindros' drawings present details that the published maps do not report, some sections are wrong (e.g., in reverse), in the archives not all original maps and sections survived, and it is not possible to detect some layers in all parts of the site (Houby-Nielsen 2015; Houby-Nielsen 2016).

- Some lack of accuracy is present in the maps used to identify the sanctuary's exact position in the modern landscape.
- The relative reference measurement system used by the SCE does not rely on any geographical coordinate system, causing difficulties in reconstructing the site with respect to the modern landscape.
- Some inconsistencies in the maps regarding the statuettes' position are visible.
- Finally, the area of Ayia Irini is not accessible for further archaeological investigations (Figure 4.40). Moreover, today the archaeological remains are not visible anymore because they are underneath.

Figure 4.40
Map of the sites excavated by the SCE during its activity in Cyprus (adapted from Karageorghis et al. 1977: 6). The Ayia Irini sanctuary is in north Cyprus currently occupied by Turkish troops (the red line shows the border).

Therefore, to face the identified issues and enhance the site interpretation, I performed a digital reconstruction of the sanctuary, the excavation context, and its material in a 3D GIS environment.

The procedure involved digitising the excavation documentation and creating a 3D reconstruction of the sanctuary by extruding elements of 2D plans and drawings.[240] Next, I recreated the stratigraphic context within the xyz virtual space and re-positioned the 3D models of the finds in it. This process contextualised the finds spatially and gave unified access to the whole assemblage.

The digital reconstruction of the site helps to question the nature of features described in the excavation documentation, such as natural events, human-made features, and the impact of flooding. It also affords a deeper examination of the positioning of finds, their setting in the sanctuary, and spatial relationships between objects, natural features and the built environment.

Furthermore, creating such an investigation environment allows a spatial distribution analysis of finds. A 3D digital reconstruction of the levels and the structures and the digital positioning of the 3D statuettes' geometry in levels want to provide a reconstruction of the original setting to obtain new visions into their positions. Successively, the reconstructed digital space allows comparing the results of the traditional classification and those of the (semi) automatic one obtained through the application of the current research methodology for an enhanced interpretation both of the material and of the site and the various dynamics occurred (e.g., production, function, and social role).

Table 4.6
List of the available material for the 3D GIS.

List of the available material
DTM 1: 25 of Cyprus
Esri imagery of Cyprus
Cadastral map of Cyprus (Department of Land and Survey, Cyprus): http://eservices.dls.moi.gov.cy/#/national/geoportalmapviewer * Cadaster map of Cyprus realised in 1919 and revised in 1935
Coordinates of the Ayia Irini position: 35°18'4.98"N 32°57'3.17"E
Plans and sections from Gjerstad et al. 1935
Plan by Houby-Nielsen 2016

240 Chapter 3 explains how it is possible to three-dimensionally represent the reality around us (a landscape, a building, an object, or part of an object) through digital survey techniques. Beyond the creation of reality-based three-dimensional models generated by the technologies described, other 3D modelling techniques exist (Russo et al. 2011:170). These are based on plans, maps, or drawings from which through the elements' extrusions, possibly applying architectonic, static, or geometric rules, is possible to generate 3D structures or objects (Müller et al. 2006; Yin et al. 2009).

PLAN XXII

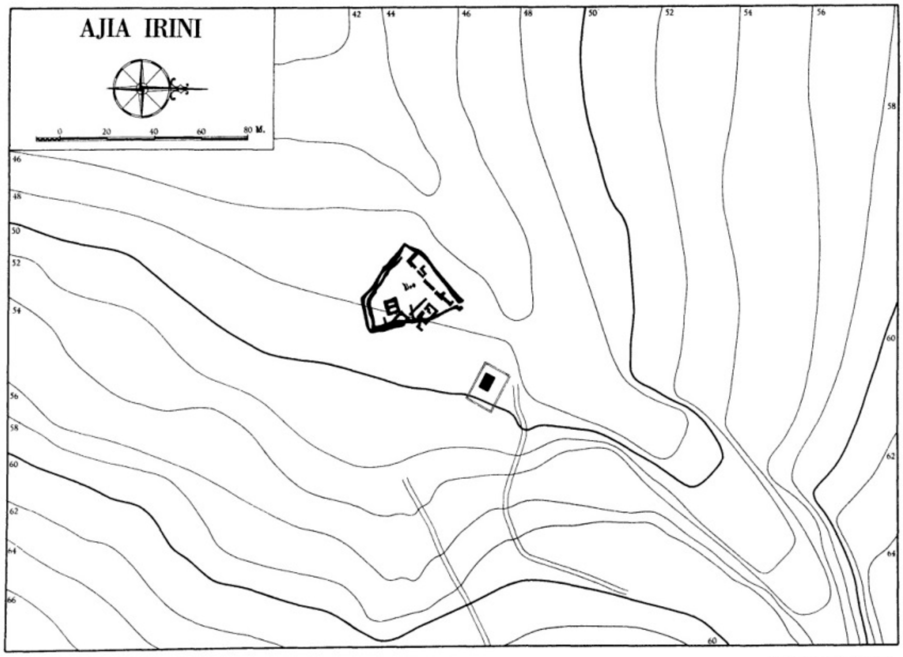

Figure 4.41
Plan XXII (Gjerstad et al. 1935: 643). The plan’s scale is 1: 80.

I planned and built a GIS project using ESRI ArcGIS Pro 1.3 software. The choice of this software is because it can manage 3D geometrically complex models and specific tools that, at the moment, are not available in other software. The first step consisted of gathering all available material regarding the Ayia Irini excavation useful to the project's construction. I combined and integrated several source materials to support the methodological framework useful to this part of the research (see Table 4.6).

I imported a Digital Elevation Model (DEM) provided by the Department of Land and Survey (Cyprus) with a resolution of 1:25 m, associated with imagery of the island of Cyprus, provided by Esri. I used it as a basemap to create the current elevation model.

Next, to better visualise the terrain as a 3D object, I calculated the *hillshade* to emphasise its topographical discontinuities, identify landscape features, locate natural anomalies, and calculate its slope.[241] This calculation allowed visualisation of the ground for comparison with the isolines in the *SCE* plan (Gjerstad et al. 1935:643, Plan XXII; Figure 4.41). Although the hillshade visualisation is based on the DEM resolution (1:25), the slopes of the terrain became much more visible, and they helped to better position the plan during the georeferencing process. A substantial part of the project consists of georeferencing all architectural plans, excavation maps, and images available to position the sanctuary and its finds in the geographical space and successively visualise and analyse them together.

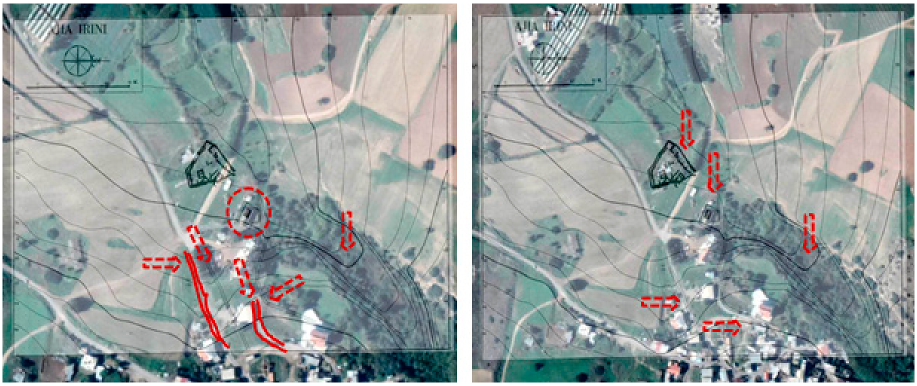

Figure 4.42
Georeferencing tests for finding the exact position of the sanctuary. The procedure uncovered problems with SCE measurements (Vassallo©).

The first question to emerge regards the exact position of the sanctuary. To determine its position in the modern landscape, I georeferenced Plan XXII by the SCE (Gjerstad et al. 1935) since it is the only official information regarding the location (Figure 4.42). Plan XXII provides the drawing of the sanctuary and some references in the space: the map orientation, a modern building that should correspond to the small old church of Ayia Irini, two lines to be identified with two roads, and isolines to describe the different height of the terrain and that help to identify the position of a stream.

Some issues came out from this phase of the reconstruction. During the georeferencing, I tried to overlap all reference elements drawn on the map: the slopes of the terrain, the stream bed position, the two small roads, and the

[241] The hillshade is a raster that enhances the terrain's three-dimensional appearance by using light and shadow patterns to create a 3D representation of the surface and make it easier to identify landscape features.

church building with its enclosure. The operation highlighted issues with measurements of elements and scale in the plan (e.g., the church and the roads). Measuring the elements represented in the map, it appears that the church does not present real measures: the church should measure approximately 14 meters, while the one drawn on the map is almost half (ca. 8 m). The measurement of the church enclosure seems more precise but not accurate. Unfortunately, this is common in maps created with manual instruments. Some dimensions do not correspond to reality, and most probably, there are small errors in the position of the elements and the scale of the plan. The errors became more evident while overlapping the drawn elements of Plan XXII on the DEM elements: the process caused their distortion and consequently changed the measurements. I identified an uncertainty of 2 meters from the historical plan on an absolute distance of 60 meters, taken at clear identifiable points on the landscape map. Therefore, to avoid that, the decision was to georeference the plan keeping the raster image's measurements stable by introducing a frame built within CAD to the map. I also employed this solution for the other maps to keep the measurements and the elements' positions stable since errors would be present in other plans, which would have increased the error.

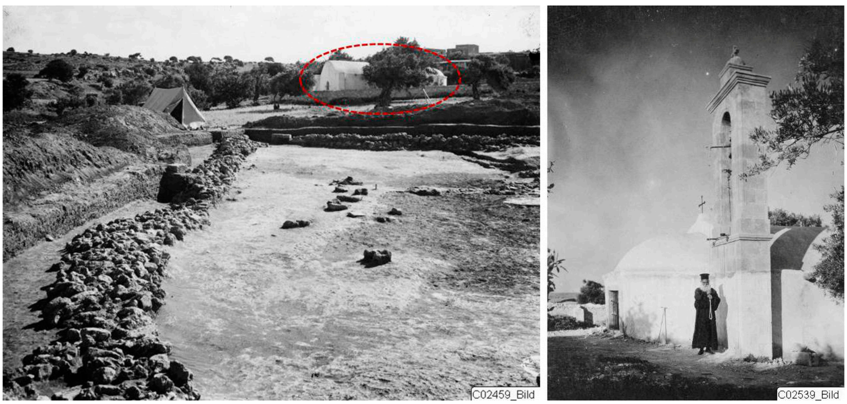

Figure 4.43
View from the sanctuary of the small Ayia Irini church (C02459 http://collections.smvk.se/carlotta-mhm/web/object/3924483) and Papa Prokopio on the back of the church (C02539 http://collections.smvk.se/carlotta-mhm/web/object/3926565).

Old photos and photographic documentation can help archaeologists to enhance the interpretation of past excavations, to identify better parts of the landscape (e.g., slopes and rivers), human artefacts (e.g., modern and ancient buildings), and relative distances between those elements, or for the whole reconstruction of ancient landscapes. Many examples demonstrate using archival data to support contemporary archaeological interpretation (Burke 2001: 224[242]). For instance, researchers consult archival photos and drawings for the virtual reconstruction of ancient structures and their decorations (Forte 2007) and use aerial photographs and old photos to reconstruct archaeological landscapes (Clark & Casana 2016).

In this vein, I used the old photos from the SCE archive (conserved at the Medelhavsmuseet) to obtain further information regarding the sanctuary's location and the finds' position. For what concerns the identification of the sanctuary's position, some of the old pictures show the view of the small Ayia Irini church from the ancient site during the excavation; others depict Papa Prokopio, the priest whom SCE cites as finding a statue in his fields, next to the church (Gjerstad et al. 1935: 642)[243]. I compared the position and direction of the church, the position of the bell tower and the apse with respect to the ancient remains in the pictures with Plan XXII, the DEM, and surface recognition[244]: the integrated activities helped locate and put in a better direction the ancient sanctuary, no longer visible today (Figure 4.43).

Nevertheless, we must always consider that photos may include human errors like any other documentation. In the Ayia Irini site, for instance, it seems plausible the archaeologists took photos after the excavation, and the assemblage appears re-arranged, leading to later confusion and misinterpretation.

[242] As underlined by Januarius and Teughels, "Peter Burke's book on the uses of images as historical evidence has brought an authoritative contribution to a theoretical and historical approach to visual material. Published in 2001, it is still very influential today. Burke evaluates different types of visual material, stressing both their strengths and their pitfalls as research subjects. Although he raises the idea that photographs bring the historian face to face with history, he also underlines the potential of visual sources as traces of the past in the present" (Januarius & Teughels 2009: 668-669).

[243] It is interesting to highlight how the church's presence confirms the continuity of use of the area as a religious one.

[244] In spring 2018, I performed a private surface recognition of the sanctuary and the neighbouring areas. The survey allowed me to identify the presence of some remains (most probably of the sanctuary) that I considered to locate the site better.

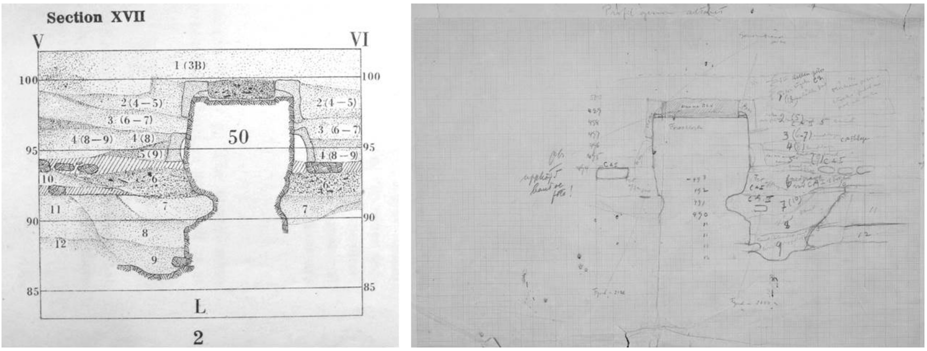

Figure 4.44
Wrong publication (and interpretation?) of some sections: Section XVII as published in Gjerstad et al. 1935 (left) and the same section as retrieved in the excavation diaries (13950D, http://collections.smvk.se/carlotta-mhm/web/object/3991070) (right).

The Ayia Irini archaeological site reconstruction's successive step consisted of integrating the more detailed plans with sections created by the SCE, both published and unpublished. In fact, beyond the measurement issues, there are differences between the published material and the excavation diaries data. As Houby-Nielsen underlines in her analysis of the SCE archive (see Chapter 2), although numerous section plans were published, only some of the originals survived there. Furthermore, it is possible to detect some inconsistencies between the excavation photos and the original drawings of the arch. Lindros with the published one: the SCE published some sections in reverse[245] (Figure 4.44); other plans present missing parts, most probably not understood and therefore eliminated in the final publication, or changed and integrated to embellish missing or not well-preserved parts (Houby-Nielsen 2016).

Additionally, it is impossible to identify all the layers of the site. In 1935, Gjerstad published the site's stratigraphy with eighteen section drawings covering different parts of the excavated area (Gjerstad et al. 1935:653-663). The publication documents twelve layers, which it is impossible to identify in the whole area, associated with seven different periods on the site.[246]

[245] Moreover, according to Houby-Nielsen, none of the originals and the published sections give proof of the floods' existence (Houby-Nielsen 2016).

[246] Gjerstad further confirmed this interpretation in his supplementary notes to the SCE publication (Gjerstad 1963: 4).

These problems with documentation raise questions about the interpretation of stratigraphy. Can a combined 2.5/3D[247] visualisation and analysis enhance our interpretation and contribute to the archaeological discussion? For this reason, I integrated the original section drawings and some redrawn maps into the 3D GIS environment to analyse them together with published ones.

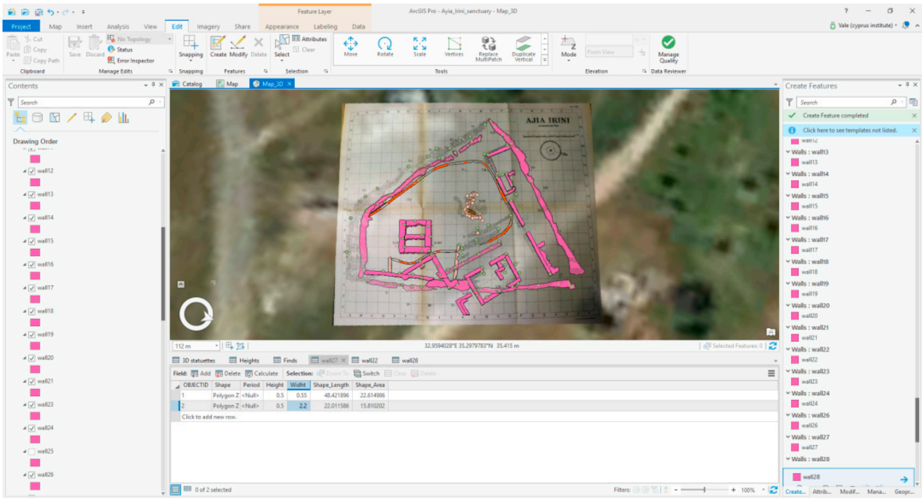

Figure 4.45
2.5D reconstruction of the structures: the geodatabase contains information about the heights and widths of each wall (Vassallo©).

Therefore, it was necessary for an earlier reconstruction of the architectural remains. The site remains buried and, therefore, impossible to document digitally (e.g., with a laser scanner or photogrammetric technique). The only solution was to reconstruct the walls as they were at the excavation with the help of the measurements and the heights' points provided by the SCE, respectively documented in the published material and by the architect Lindros' original drawings. The integration of the full information available aims at understanding the relations between the structures, the levels, and the finds. I stored the absolute heights and thickness of the sanctuary walls in the

[247] The use of the hybrid 2.5/3D term is because in this case-study there is not a 3D digital documentation of the structures (currently not accessible) and I reconstructed them estimating depth of archaeological features and thickness of walls from excavation data previously stored in the attribute table to extrude polygon features in a 2.5D georeferenced environment. See further for a detailed explanation.

geodatabase to extrude the polygon's features in the 3D georeferenced environment (Figure 4.45). We can technically define extrusion as a 2.5D operation to vertically re-project a vector polygon based on fixed z values. In the case of the Ayia Irini structures, the final result of the extrusion provided an acceptable approximation of the original volume. The constant thickness value of the sanctuary walls reported by the SCE facilitated the operation.

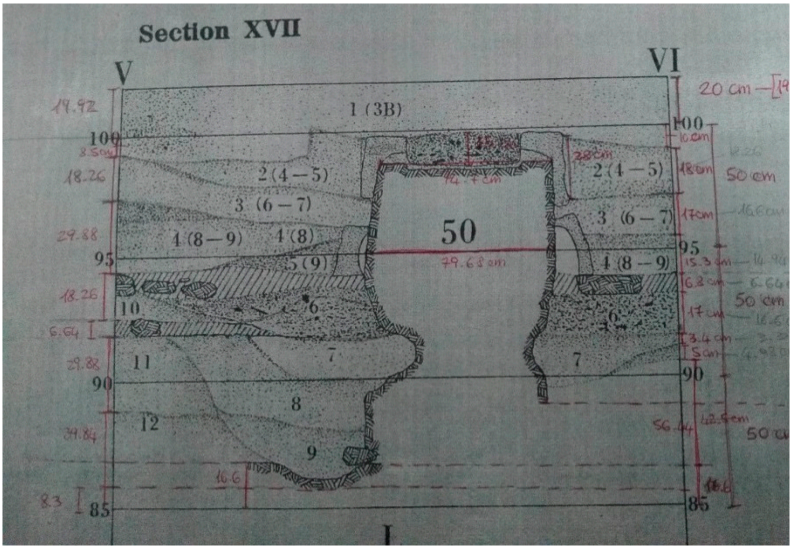

Figure 4.46
Calculation of the layers' depth in relation to the levels published by the SCE in Section XVII (Vassallo©).

This phase also included reconstructing the structures' position compared to the modern landscape. This step was the most problematic since no SCE document reported information about the datum point. I inferred information regarding the estimated depth of the archaeological layers and the walls' height position with respect to the current terrain level by transforming the levels' point reported by the SCE to a relative reference system where the new level 0 coincides with the SCE level 100. I chose level 100 as a reference because SCE documented it in Section XVII with respect to the altar and at the centre of the area where the excavation started.

I calculated every layer's depth to create a database of the measurements to reconstruct the stratigraphy (Figure 4.46). The successive step consists of integrating all the features in the exact places (as the original drawings) and then building the 3D volumes, where I integrated and analysed the 3D finds

(Figure 4.47). By integrating this data, we obtain an enhanced interpretation of the site. Reconstructing the original setting allows us to obtain new visions into their positions. This integration clarifies the different scholars' opinions regarding the occurrence of several episodes of natural flooding (two to four) or human-made settings identified within the excavation. The data also contributes to a classification strategy.

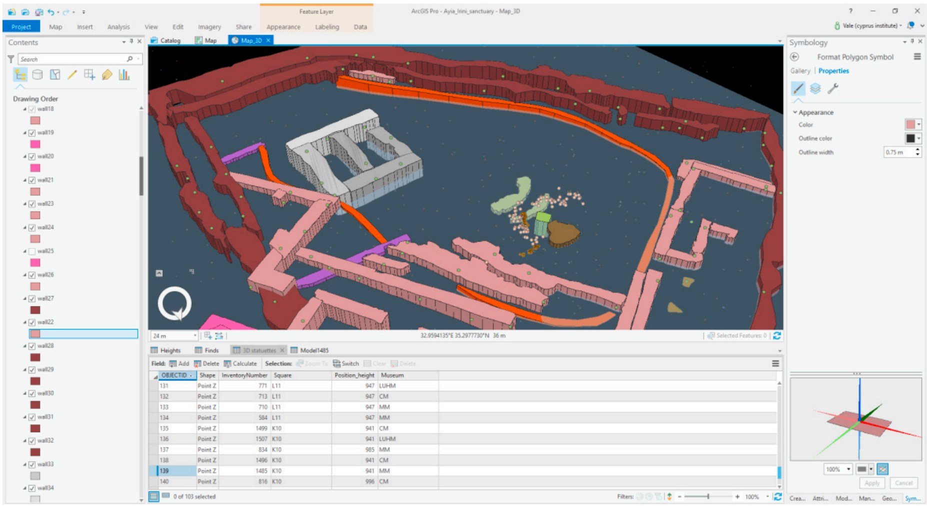

Figure 4.47
Reconstruction of the excavation: 3D layers and positioning of the 3D finds (Vassallo©).

I imported the 103 artefacts' 3D models[248] into the geodatabase with other data to visualise and analyse them (Figure 4.48). Concerning the rest of the Ayia Irini finds for which 3D models are not available[249], I considered only the position in the space so far (the SCE provided measures, positions and height points for all the material excavated) to simulate the interaction with the other elements. This step aims to reconstruct and visualise exact positions and layers; it helps obtain a better view of the number of floods that occurred on the site and their effect on the artefacts. The archaeological *querelle* focuses on two or four floods and the different interpretations of the archaeologists.

248 The 3D models I used are those I generated with laser scanning since I needed only the geometry and not the texture

249 My ambition is to digitise all the artefacts and prosecute this research in the future to obtain a complete study of the site and its collection.

The SCE archaeologists provided information about the position of each find. In his drawings, the architect Lindros took note of the heights' points of the walls, while the excavation's text reports the height's points of each find.[250]

It is essential to highlight that a closer analysis revealed that the SCE Plan XXVIII ('Plan of finds in situ') is a 'hybrid' between a geometrical plan and an artistic sketch. It represents the altar with the right measurements and associates the finds' position with the squares which organise the excavation space.[251] However, many finds do not present exact measurements; the plan roughly represents their inclination and, in some cases, does not provide their inventory number or report a wrong one.[252] Moreover, the plan presents a frontal perspective. Still, if we look at it from another viewpoint, differences in the artefacts' inclination with respect to the terrain and the other finds appear.

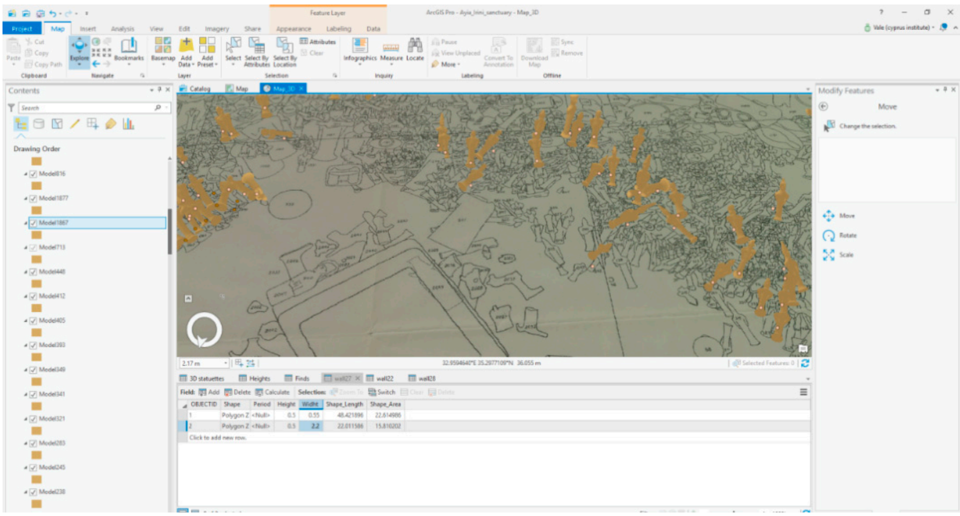

Figure 4.48
Import of the 3D finds in the geodatabase. The positions and heights points have been documented (Vassallo©).

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[250] Nevertheless, the documentation does not specify where the surveyor took each find's point (on top of the object, at its base or on the terrain just under the object).

[251] The accuracy of these elements is sure because they helped to georeference the plan for the integration in the project.

[252] Like what happened for the assemblage interpretative study, more importance is given to the big statues rather than the statuettes.

Another issue is that the architect Lindros seems to have arrived on the site after excavating the votive statues and documenting them as one assemblage (Westholm 1994:7-21). Sjöqvist identifies only two floods: one before the artefacts were put in place and another after; he, therefore, documents the votives as one assemblage, not disturbed by intermediary floods. This might also explain why the plan represents the final phase of the statues' excavation, without any partial plans of the stratified artefacts dismantling. Gjerstad explains the stratification and the periods as a consequence of four floods. In his view, after every flood, the worshippers left the older votives *in situ* half covered by the debris, while they added the newer figures on the more recent floor levels, giving evidence of different periods (Gjerstad et al. 1935). Comparing all data, such as the inventory numbers list, photographs, and plans, helps us better understand the situation during excavation.

Successively, I calculated the heights' points of the finds to see if an analysis of the relation between the 103 sampled statuettes and the layers' heights could provide any results in identifying specific material settings. It is important to underline that this is a partial calculation and reconstructive hypothesis since the test considers only the sampled artefacts. At the same time, a complete analysis would need to involve the entire collection. Based on the earlier calculation performed on Section XVII (Figure 4.46) to reconstruct each layer's depth, the overall archaeological depth is 150 cm; therefore, each unit equals 10 cm. The analysis shows that the 103 sampled statuettes lay between the height's points 93.1 and 101.0, a space equivalent to 80 cm[253]. Then, I calculated how many are in each unit and their spatial vertical location. Figure 4.49 shows the overlap of the resulting statuettes' spatial vertical location on top of Section XVII to show their distribution within the area considered.

[253] The statuettes measure from a minimum of 20 cm to a maximum of 27 cm.

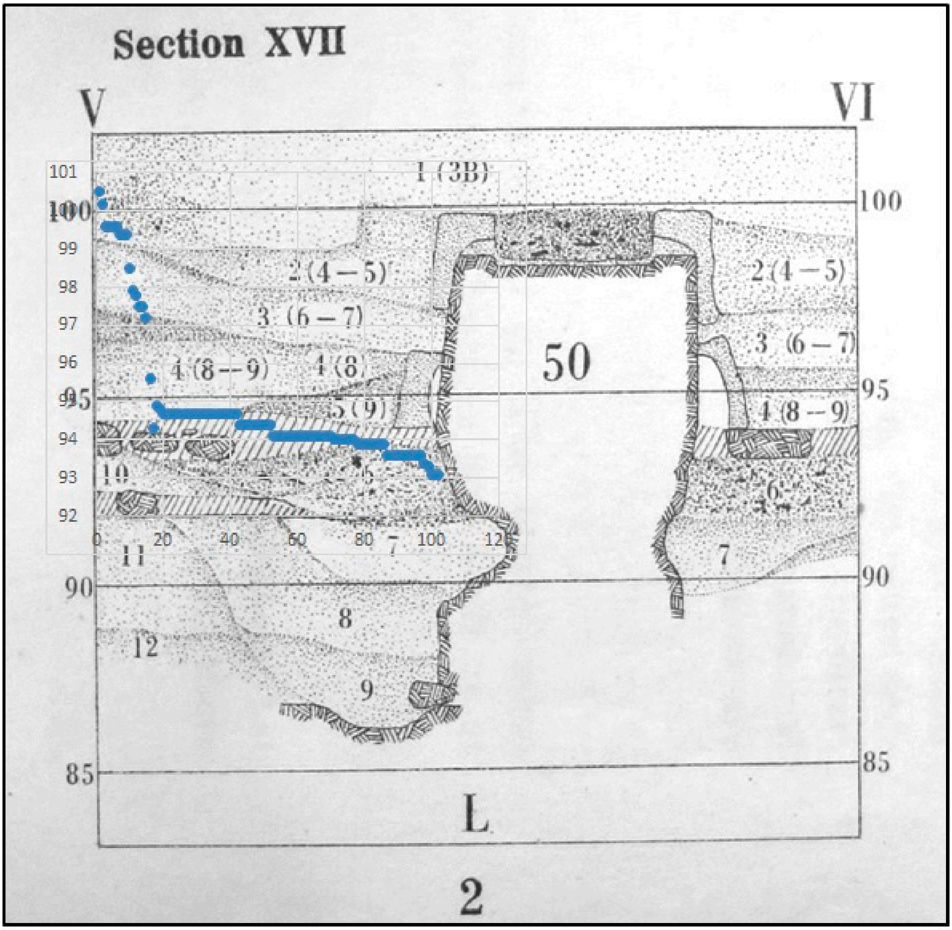


Figure 4.49
Superimposition of the spatial vertical location of the sampled statuettes on Section XVII (Vassallo©).

Looking at Figure 4.49, we can notice the following. The z-axis distribution of the sampled figurines shows that the vast majority (N=86) are within a 20 cm range, between relative heights of 93.1 and 94.9. Another possible group of figurines is within the range of 97.2 and 99.6 (N=13). According to this analysis, we can assume one main layer of human activity at a relative height of 94 and the second one of a much smaller intensity, located approximately 40 cm higher, at a relative height of 98.4. It is important to note that in this assumption, we did not calculate any other rotation axis. This analysis considers a partial number of statuettes (the 103 sampled). However, the presence of two main archaeological events is visible, divided by an interval, Layer 4. That layer is the only one the archaeologists explicitly identify as made 'of alluvial sand' with respect to the others they describe as mixed with sand and not surely identifiable with flooding events (Gjerstad et al. 1935: 663). Additionally, detecting a rarefaction in the small statuettes positioning towards the more recent periods is possible.[254] Therefore, the subdivision suggests two major stratifications that might indicate stratification (chronological or human-based) if not proof of floods.

The digital reconstruction of the sanctuary and its excavation in the 3D GIS environment allowed identifying and solving various issues. These new elements are fundamental for enhancing the site's interpretation and creating an accurate space that successively integrates the results of the previous investigations. In the next chapter, I will present the geometric and analytical investigation results, the semantic documentation, and the integration and comparison within the re-assessed chrono-spatial context. This step contributes to an enhanced interpretation of the figurines' *chaîne opératoire* investigation and the definition of a novel strategy for classifying the archaeological material and its interpretation.

4.4 Semantic analysis

The last part of the methodology consists of integrating all data, and its semi-automatic cross-check. This step helps validate the results obtained by applying the 3D digital and analytical *chaîne opératoire* methodology developed for this dissertation.

As treated throughout the research discussion, the approach in the study of the statuettes focuses on observing and analysing the objects' production, aiming to identify different aspects of the techniques and the *chaînes opératoire* followed for their manufacturing. We can recognise these aspects in recurrent elements attributable to the same individuals or the same workshop.

The statuettes reflect elements of their conception and creation. Therefore, the classes determined by applying the 3D digital and analytical *chaîne*

[254] Moreover, the statuettes' analysis shows a change of typologies towards the upper level of the assemblage respect to the previous ones. According to Houby-Nielsen (2016) the setting could also follow a deposition order decided by other criteria than time, such as clusters of similar objects according to different social status or ethnic origin of the worshippers and places of display.

opératoire methodology can provide information about the artefacts' creation: every part, variations of those parts, and their combinations represent the choice of the artisan who created them (Alexandrou 2016: 55, 71). I identified variations and similarities in this research sample related to the production of specific artisans' hands/workshops. The elements and parts of the statuettes represent the artisans' specific choices and allow the creation of groups of terracotta characterised by their common production mode.

Therefore, it is important to test the quality of the results and their acceptability range before attributing a common hand. For instance, the association of a feature with specific others can support the attribution to the same artisan's hand; a variation within a combination can explain a slight difference by the same hand or the production by a completely different hand.

For this reason, I created a detailed Excel table for the semantic description of the figurines, entering all data under study. Then I conducted a cross-check comparison (Table 4.7 shows an excerpt of the Excel file). Specifically, I obtained that through the table sorting and filtering options based on multiple fields (e.g., type, accessory and pigment). The table reports all the parts of the figurines bodies (e.g., beard, hat, arms, attire, accessories, decoration) and their variations (e.g., painted/added beard, truncated/pointed/turban hat, arms postures, presence of tympanon/animal, ladder-pattern decoration), as for the partonomic description. Moreover, in the structured table, I added the results of the analyses carried out by applying the geometric analysis and the physico-chemical investigation (e.g., extracted measures, head clusters, pigment composition) together with those of the earlier scholarships. Eventually, since the context has an important role in the analysis and interpretation of the material, I included the information regarding the sanctuary (e.g., space, figurines' position, height level, and layers).

The final analysis through filtering options aims to retrieve and test in the figurines under investigation the presence of a combination of common or repeated elements that might have a social significance regarding the production, such as the specific choices of an individual and, consequently, the attribution of those artefacts to the same hand/workshop (see 5.1.4). For instance, the system highlights and groups elements that represent variations in the production between the statuettes of the assemblage (e.g., specific rendering of a part of the body, the same decoration, the presence of a recurring sign) according to their similarity (Alexandrou 2016: 19-20). This procedure helps to evaluate and confirm the results obtained through quantitative analyses.

Table 4.7
Excel semantic table for validating the results obtained by applying the 3D digital and analytical chaîne opératoire methodology. The software filtering options allow cross-checking the data (the table here reports only some fields of the original Excel file).

ID	TYPE (SCE)	TYPE (Fourrier)	TECHNIQUE	MOULD	HAT	BEARD	ACCESSORY	DECORATION	PIGMENT
A.I. 28	Type 6	Imports from Idalion	Handmade	-	Medium pointed hat	Painted beard	Mantle	Lonzanges lines	-
A.I. 37	Type 6	Imports from Idalion	Handmade	-	Turban (missing)	-	-	-	-
A.I. 60	Type 6	Imports from Idalion	Handmade	-	Medium pointed hat	Painted beard	-	Lonzanges lines	-
A.I. 83	Type 7		Wheel-made	Mould x	-	-	Mantle	Lines	-
A.I. 649	Type **5**/6	Soloi A1	Handmade	-	Short pointed hat	No beard	-	-	No colour
A.I. 771	Type 5	Soloi A2	Handmade	-	Long pointed hat	No beard	Mantle	-	No colour
A.I. 816	Type		Handmade	-	Turban?	-	Phorbeia	Knap-sack	-	Orpiment
A.I. 842	Type 5	Soloi A1	Handmade	-	Long pointed hat/truncated	No beard	-	-	No colour
A.I. 1223	Type 5	Soloi A1?	Handmade	-	Turban	No beard	-	No decoration	-
A.I. 1299	Type 5	Soloi A1	Handmade	-	Medium pointed hat	No beard	-	No decoration	-
A.I. 1507	Type 5	-	Wheel-made	Mould y	-	Painted beard	-	Ladder band	black lines
A.I. 1547	Type 5	Soloi A1	Handmade	-	Long truncated hat	No beard	-	No decoration	-
A.I. 1548	Type 5	Soloi A1	Handmade	-	Long truncated hat	No beard	-	-	-
A.I. 1587	Type 5	Soloi A1	Handmade		Medium pointed hat	No beard	-	-	-
A.I. 1916	Type 5	Soloi A1	Handmade	-	Turban	-	-	-	-

5. Archaeological Interpretation

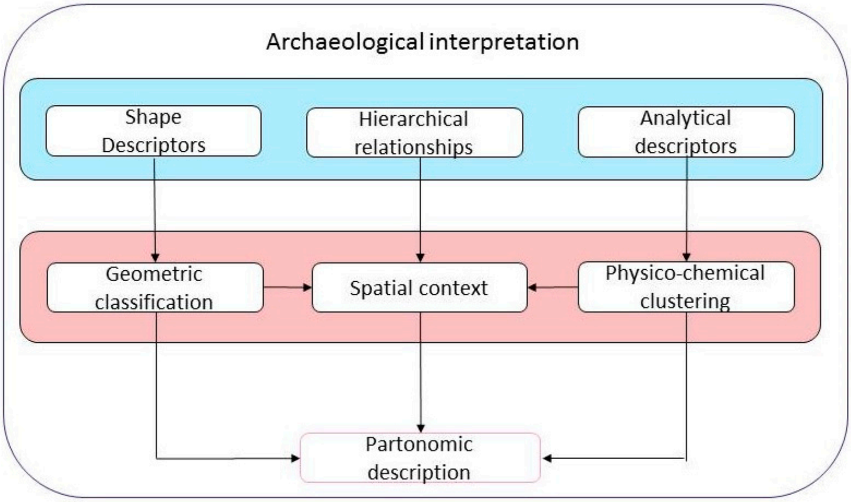


Figure 5.1
The research methodology for the interpretative step integrates results of the multidisciplinary analyses and explains them archaeologically (Vassallo©).

The final step of the research methodology developed in this thesis (see Chapter 3) integrates all the results obtained through multidisciplinary analyses for their archaeological interpretation. Specifically, it combines the results obtained from the shape analysis (the new groups of figurines) with the information from the physico-chemical investigation. Consequently, the procedure continues with the spatial re-contextualisation of the groups to explain the connection with their *chaîne opératoire*, both in terms of material production (e.g., common hand/workshop identification, materials) and of chronological relations (production and deposition). Finally, we compare all data through the semantic partonomic description for a semi-automatic cross-check aimed at the results' evaluation (Figure 5.1).

As described in Chapter 2, the collection combines various techniques: wholly handmade statuettes, handmade arms combined with wheel-made bodies and moulded heads, handmade elements attached to moulded heads, and presence/non-presence of decorations. Within the small figurine group, the solid handmade ones are the majority (see Gjerstad et al. 1935; Ikosi 1991-92: 303, figure 27). The production of the handmade statuettes was straightforward: an artisan could have easily reproduced it by modelling a cylinder of clay, making it thinner towards the head, modelling the head, adding rolls of clay for the arms, and finally adding details on the head such as pellets of clay for the ears, and a piece for the noses (Ikosi 1991-92: 272). The wheel-made statuettes consisted of modelling the body on the wheel, moulding clay for the head, adding to the body using a clay tenon, and then modelling clay rolls for the arms. Therefore, employing several different techniques could show, even on a single object, the possible combined work of a coroplast, a potter, and a painter.

The SCE excavation records do not comment on production and provenance. Sabine Fourrier proposes a production provenance from different areas based on stylistic reasons. Vassos Karageorghis argues that decorative patterns suggest that Cypro Archaic I and II workshops might have produced terracotta statuettes alongside pottery (Gjerstad et al. 1935; Fourrier 2007; Karageorghis 1995[255]). We have evidence that the same potters and artists created and painted statuettes and vases alongside other clay objects, including lamps and roof tiles. Other scholars propose that separate workshops might have specialised in specific productions (Biers 1994: 513). These various cases certainly complicate the actual comprehension of the work's organisation during that time, not excluding the different solutions' co-existence. Another interesting question involves the workshops' arrangement, which suggests the presence of a 'maker' and a 'decorator', justifying in some cases the small number of specific products or their ease of manufacture. Of course, this is not the only possible solution; for example, we could attribute the presence of moulded heads to production by a specialised 'coroplast' (e.g., the master artisan). There might be other solutions and models (that could resemble modern and contemporary artisan production).

In this vein, another element to consider is the existence of any degree of specialisation within workshops. An example of production specialisation in the text sources can be found in Xenophon (*Cyropaedia 8.2.5-6*), who underlines how the tasks' division requires specialisation and results in an

[255] Nevertheless, Karageorghis does not exclude the presence of individual artists due to some variances in the decorative patterns or their complete lack.

extraordinary product.[256] Although the 4th century BC historian Xenophon refers to other kinds of workshops and jobs, shoe-makers and house-holders, and he is chronologically posterior respect with Ayia Irini, we can easily transfer the paradigm to a coroplastic/pottery workshop of the Archaic period, opportunely adjusted considering the smaller and more regional approach suggested by Fourrier (2007). Likely, we have to consider that, as Biers argues and the number of Ayia Irini figurines demonstrates[257], a specialisation would result in increased quality, not productivity (1994: 509).[258] Moreover, as Botwid experimentally explains (see Chapter 4), and Biers proposes, based on Plato's thoughts[259], pottery workshop production relies on an apprentice system and possible differentiation of the work (Botwid 2016; Biers 1994: 514). Possibly, the work organisation allows identifying some elements that could provide information on the crafters' level of expertise.[260]

The work's specialisation and organisation might bring to the standardisation of the procedure, and consequently of the products, following 'official' canons or organisational settings and 'rules' followed by a

[256] Xenophon states: *(5) "[...] Now it is impossible that a single man working at a dozen crafts can do them all well; but in the great cities, owing to the wide demand for each particular thing, a single craft will suffice for a means of livelihood, and often enough even a single department of that; there are shoe-makers who will only make sandals for men and others only for women. Or one artisan will get his living merely by stitching shoes, another by cutting them out, a third by shaping the upper leathers, and a fourth will do nothing but fit the parts together. Necessarily the man who spends all his time and trouble on the smallest task will do that task the best. (6) The arts of the household must follow the same law. If one and the same servant makes the bed, spreads the table, kneads the dough, and cooks the various dishes, the master must take things as they come, there is no help for it. But when there is work enough for one man to boil the pot, and another to roast the meat, and a third to stew the fish, and a fourth to fry it, while someone else must bake the bread, and not all of it either, for the loaves must be of different kinds, and it will be quite enough if the baker can serve up one kind to perfection—it is obvious, I think, that in this way a far higher standard of excellence will be attained in every branch of the work"* (translated by Miller 1914, www.perseus.tuft.edu).

[257] Indeed, the quantity of the Ayia Irini statuettes shows a considerable number but not so significant to justify a sort of 'industry' production.

[258] Specifically, Biers disagrees with the past general belief that in antiquity, the increase of the demand for a specific product results in an increase of production and consequently a lower quality (see the concept of 'poor craftsmanship' in Burford 1972: 107).

[259] Plato, Republic 421e, 466e, 467a.

[260] According to Shimelmitz (2016), we can connect the production's organization, the different levels of specialization or different manufacturing with the increasing production of commodities.

workshop, an artisan, or by a small group of people collaborating in the production of specific goods. For instance, regarding the presence of 'official' canons, Judith Weingarten reminds us that artisans reproduced the human figure in different media (e.g., depictions, statues) following specific systems: the Mesopotamian method according to which they divided the body into parts of 1/6, the ideal Egyptian proportions of the body set into an 18 units grid, or the famous Greek and Roman 10 parts' canon, known through Vitruvius (*De Architectura, II, 3.1*), for sculpting human statues (Weingarten 2000: 103). Certainly, the production of small, common figurines, easy and fast, differs from large, artistic pieces. Nevertheless, we can intend the standardisation in this context as a set of rules handed down from master to apprentice to create a figurine able, for instance, to last or stand (e.g., proportions between height and base) and to facilitate its production. Specifically, in this study, we can consider the standardisation of a series of rules learned by an apprentice within a workshop (*connaissance*) to carry the work out at his/her best, then used as an artisan (*savoir-faire*) and possibly handed on to other apprentices. In this framework, the admixture of rules and know-how encourages the definition and recognition of patterns and, consequently, common productions.

In the previous chapters, we addressed all these hypotheses from a quantitative point of view by applying geometric and analytical investigation. So far, as the earlier studies demonstrate, the purely visual analysis did not focus on these specific aspects and, in the case of quantitative analyses, only partially solved the hypotheses.

The combination of quantitative variables, contextualisation, and standardised semantic descriptions offers new ways to study coroplastic collections, allowing researchers to identify patterns and create new classifications. This integrated approach is especially helpful with complex and overlooked[261] collections.

The following sub-sections will present a new classification and interpretation of the small figurines' production obtained through the 3D digital and analytical *chaîne opératoire* approach.

[261] The study of small figurines is often overlooked with respect to that devoted to the big statues.

5.1 Novel classification and interpretation of the small figurines' production through the 3D digital and analytical *chaîne opératoire* approach

Comparison between earlier studies

This chapter will compare earlier classifications and studies performed in the past through qualitative methods and the quantitative 3D digital and analytical results. The comparison helps quantitatively verify the correctness of the past classification and evaluate the differences between the two methods. Before doing so, the next section will provide a commented recapitulation on the earlier studies and their relationship with the present one.

Chapter 2 demonstrated that Gjerstad's classification aimed to lay a foundation for Cypriot archaeology. For instance, his classification of the large statues follows a chronological approach, as reflected in the terminology: "proto-Cypriot", "neo-Cypriot", or "Greek-Cypriot." According to Fourrier, Houby-Nielsen and Bourgiannis, this succession of "styles" relies on the ambiguous stratigraphic data of the Ayia Irini sanctuary excavation and is unsuitable for terracotta figurines (Fourrier 2007: 14-16, 89; Houby-Nielsen 2016; Bourogiannis 2016). Gjerstad's admission that the "small human idols" are impossible to classify based on style hints that his chronological approach is problematic for those types of artefacts (1935: 39). For this reason, he shifted methods for the small figurines, relying on typologies and avoiding detailed subdivision (Gjerstad et al. 1935: 785-786).

Karageorghis does not discuss the SCE classification. His contribution to the Ayia Irini small figurines study is more from a broad point of view. He mentions some to demonstrate stylistic and typological similarities within the Cypro-Archaic production found elsewhere. He concludes that the island pottery workshops might have produced the Cypro-Archaic I and II terracottas, not excluding the presence of independent coroplasts (Karageorghis 1995: x). In particular, Karageorghis reminds us that most of the statuettes from Ayia Irini, the solid handmade ones attributed by Gjerstad to the Type 5, mainly appearing at the sanctuary in Period 4 and some also in Period 5 and 6 (Karageorghis 1995: 4). The only topic raised by the archaeologist from a classificatory point of view is when, describing the figurines attributed by Gjerstad to Type 6, underlines they do not differ much from Type 5, and in reality, there are no clear-cut characteristics among the two types (Karageorghis 1995: 5).

Gloria Ikosi faces the Ayia Irini small statuettes' study from the perspective of production technique, provenance and distribution. Relying on solid handmade and hollow wheel-made groupings, Ikosi compares the figurines with other Archaic coroplastic productions from Cyprus. She divides the known Cyprus sanctuaries into two groups based on their most common type of production: solid handmade figurines and moulded (Ikosi 1991-1992: 275). The analysis of Ikosi's data demonstrates that solid, handmade statuettes are more often found in sanctuaries near the coast. In contrast, moulded ones are more often found in those in the island's centre (Ikosi 1991-1992: 275-276, map 2). Moreover, based on clay analysis and stylistic and iconographic details, she proposes the presence of two masters working with different coroplasts (see Chapter 4). Unfortunately, this attribution coroplast/master and artefacts is not fully transparent, and it is impossible to have more hints on this new proposed sub-classification, especially for the material studied in this thesis (Ikosi 1991-92; Ikosi 1992).

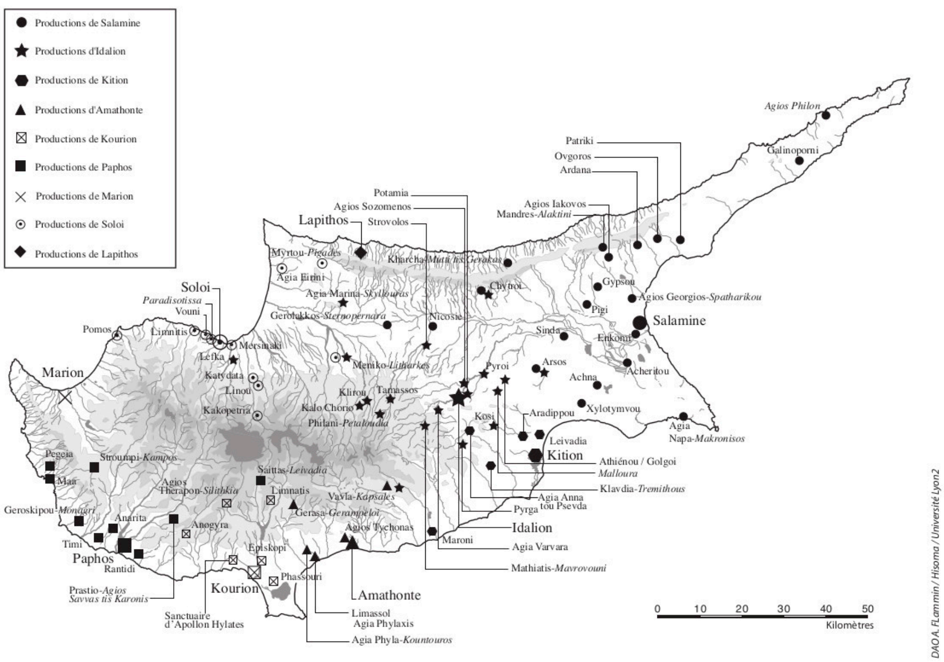


Figure 5.2
Regions of influence of different kingdoms according to the attestation of terracotta figurines during the Archaic period (Fourrier 2007: 113, fig. 9, A. Flammin, HiSoMA, univ. Lyon2©).

Sabine Fourrier analysed some of Ayia Irini's figurines to identify production groups' provenance. Compared to Gjerstad, who studied the material with a technological approach to identify a chronological pattern, Fourrier's classification relies on a stylistic and geographical methodology. Fourrier notes the inconsistencies of the SCE's stratigraphy, and she concludes that a chronological overlap in the styles exists[262], alternatively proposing, instead of chronological groups, the representation of distinct workshops of different city-kingdoms. Following Nicholls' approach (Nicholls 1952), Fourrier proposes stylistic and geographical sub-groups for Archaic Cypriot coroplastics production (Fourrier 1999; 2007).[263] Therefore, starting from the figurines' appearance and distribution, the author suggests their city-kingdoms provenance (Figure 5.2), which is similar to the geographical distribution proposed by Gloria Ikosi on the basis of the production technique. Specifically, for what concerns the Ayia Irini production, Fourrier also considered some of the artefacts sampled for the current study and some of their "reference figurines". Like Gjerstad classification for Type 5 and 6, I noted that also the two Fourrier groups "Soloi A-1" and "Soloi A-2" present "no clear-cut criteria", and we can observe this inconsistency in the similarity association of the figurines used for her groups. Therefore, if we follow the sub-division proposed by Fourrier, we can classify the sample of this dissertation according to the groups reported in Table 5.1.

[262] Specifically, she refers to the Styles of the large statues, attributed by the archaeologists to the Pro-Cypriot and the Neo-Cypriot (Fourrier 2007: 104).

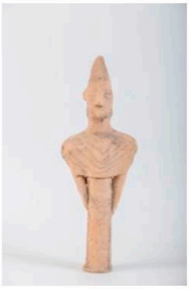
[263] The identification of production centres connected to different regions of the island based on technical and iconographic criteria -cultural identities and political territories of the kingdoms -, suggested by Fourrier (and before by Yon & Caubet 1991), set up a different approach respect to the past for what concerns the Cypriot coroplastic study (Fourrier 1999; Fourrier 2002). Specifically, her approach gathers the island production into stylistic groups to define regional cultural identities (Fourrier 2007). Within the panorama of the island's urban centres coroplastic productions, the author classifies the various stylistic groups according to the manufacturing technique and defines the distribution of these productions in "peri-urban sanctuaries", "territorial sanctuaries", and "border sanctuaries". According to the different groups of figurines distribution, for the large centres (e.g., Salamis and Idalion), she defines the outlines of "cultural" territories corresponding to political borders. Specifically, for what concerns the extra-urban sanctuaries like Ayia Irini, she proposes they played a role of display and exhibition, affirming, in the absence of monumental constructions, their cultural identity respect to the kingdom's territory (Fourrier 2007: 124; Fourrier 2013: 105).

Table 5.1
Summary of Fourrier attribution related to the figurines sampled in this study.

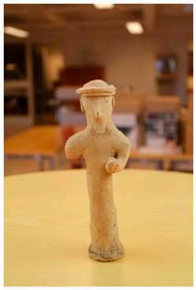
“Soloi A-1 group” (Fourrier 2007)

In the “Soloi A-1 group”, some are also included in the sample of the current research: A.I.60, A.I.816 and A.I.1916. Some are Reference Figurines: A.I.399, A.I.576, A.I.586, A.I.1219, and A.I.1258.

This group is Fourrier’s group and includes warriors, horsemen, chariots, and men with high-pointed caps and resting. The literature describes these with oval heads and a large, attached nose, fixed throughout its length on the back of the face and abutting on a marked chin, stretched forward.


A.I.60


A.I.816

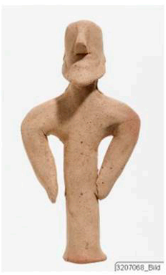

A.I.1916

“Soloi A-2 group” (Fourrier 2007)

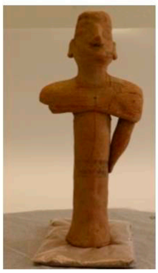
My sample has no objects from this group besides two Reference Figurines, A.I.1803 and A.I.1833. However, A.I.1711 is associated with A.I.1803, and A.I.130 and A.I.470 are associated with A.I.1833.

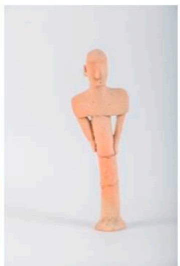
“Imports from Idalion” (Fourrier 2007)

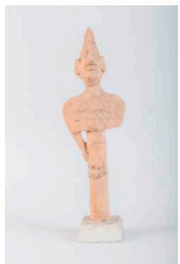
My research does not include any items from this sub-group. However, A.I.42 is a Reference-Figurine for four objects in this category (A.I.60, A.I.895, A.I.37 and A.I.28), labelled Type 6 by Gjerstad. According to Fourrier, A.I.60 falls in the “Soloi A-1 group” and not in this group, as the Gjerstad “reference figurines” would suggest.


A.I.42


A.I.60


A.I.895


A.I.37


A.I.28

“Imports from Kition” (Fourrier 2007)

Only one object from my research falls in this group, A.I.109. According to Fourrier, these kinds of statuettes might be imports from the kingdom of Kition despite having no borders in common with Soloi territory. The author proposes that local artisans create new moulds from the imported artefacts. In Fourrier’s opinion, the proof is that features of the face became almost illegible, so the artisans adjusted them by adding painting (Fourrier 2007: 58, 91).

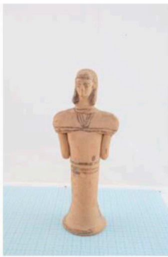
A.I.109

“Group derived from Kitian production (imports from Lapithos?)” (Fourrier 2007)

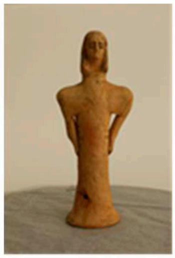
Fourrier alternatively proposes that the Ayia Irini statuettes attributed to “imports from Kition” were either made in or passed through Lapithos. According to her, this group have an exact parallel within the artefacts found in Lapithos (Yon & Caubet 1988: 10-11; Yon & Caubet 1989: 29-30), where the Kitian style gave birth to different production groups (Fourrier 2007: 91). In this group there are some statuettes that are also in the sample of this research: A.I.92, A.I.880, A.I.1499, A.I.1535, and A.I.1871.

A.I.92

A.I.880



A.I.1499



A.I.1535

A.I.1871

In the wake of the previously mentioned study on clay, the invasive analysis conducted by Mühlenbock and Brorsson to identify the material composition did not add new information to the previous classification. Brorsson identified a division similar to the one suggested by Ikosi (Brorsson 2016a). Mühlenbock and Brorsson looked at statues, statuettes, and other objects from the Late Bronze Age, Cypro-Archaic II and Hellenistic, and their analysis showed clay with similar chemical compositions, probably from clay-beds in the same geographical area. Nevertheless, a couple of artefacts from the Late Bronze Age and one from the Hellenistic period differed from the others in composition, style and technology, indicating a possible different provenance (Mühlenbock 2015; Mühlenbock & Brorsson 2016; Brorsson 2016a; Brorsson 2016b). The scholars underline that the groups that emerged from their analysis do not coincide with those created by Gjerstad, but the research did not go into further detail.

Mühlenbock and Brorsson also compared their results with those of the Fourrier, concluding that "none of the suggested imports (from other Cypriot workshops) stand out" (Mulenboch & Brorsson 2016: 305). However, such a statement requires further investigations of other terracottas from different contexts and geographical areas, plus it is very likely that at the geomorphological level, the regions proposed by Fourrier as geographic provenance present similar clay composition.[264] None of the statuettes analysed by the two scholars is in the current research sample, but some are taken from Gjerstad's Types 5, 6, and 7.[265] Therefore, the analytical results and the comments on the statuettes' previous classifications can be opportunely related to the sample studied in this thesis.

Finally, although Houby-Nielsen has not dealt with classification but has tried to understand better the excavation stratigraphy and the material arrangement (Houby-Nielsen 2016), her conclusions contribute to the discussion. She proposes social status, ethnicity or provenance of the worshippers may be a key factor explaining the location of the votives. Therefore, we may be able to use their position to obtain information on the objects and their production for their classification.

Investigation of the chaîne opératoire: production technique, level of expertise, specialisation and work standardisation

This thesis' methodology adds to the previous studies' results additional information.[266] So far, for the Ayia Irini assemblage, there was no holistic study to provide insights on the artisan(s) technical skill or specialisation levels in the figurines' production within the manufacturing environments.

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264 Their statement does not want to be an attack on the goodness of Gjerstad's typological division and Fourrier stylistic classification; it is more to underline the need for further investigations of other terracottas from different contexts and geographical areas to compare the results of the typological/stylistic and analytical studies.

265 It is interesting to notice that also for the specimens selected in that research (Mühlenbock & Brorsson 2016: 302-303), the scholars show their indecision to attribute the statuettes to a specific Gjerstad Type (e.g., A.I.3040 - Type 5-6). Moreover, I identified mistakes in attributions to specific types (e.g., A.I.994 attributed to Type 6 instead of Type 7).

266 This research does not reject the typological/stylistic approach used in earlier research for chronological and geographical provenance/distribution aims (Fourrier 2007) but accepts and grants their results.

Relying on the chaîne opératoire approach, I identified features, such as manufacture, skill, expertise level, specialisation and standardisation, to obtain a classification of sub-types that we can attribute to specific hands/workshops.

Moreover, we can use the artisans' deliberate choices and the specific traits deriving from those choices to identify the common hands/workshop on the artefacts. For instance, specific repeated elements could be artisan's choices, giving information on the manufacturing procedure and helping to identify (sub)typologies (Alexandrou & O'Neill 2013: 2; Alexandrou 2016: 22, 24). Indeed, in studies of assemblages, although there is a strong relation between technological behaviours and social groups -and therefore between the individual and the group to which s/he belongs (Roux 2017: 2, 4)- it is possible to identify individual traits within it.

Even in the work of one craftsperson, we might find variations, making it difficult to differentiate between an individual creator and a group. Christine Morris addressed this problem with the so-called 'analytical individual' groups (Muller 1977: 25), in which all the similar objects would justify the production by the same hand (Morris 1993: 47). Later, Constantina Alexandrou experimentally tested the theory on figurines (Alexandrou 2016: 127 et seq.) and qualitatively identified primary and secondary elements, representing respectively those that remain consistent in an artisan work and those subjected to variations between artefacts or through time.[267]

This study achieves a further step. The Structuralists' chaîne opératoire approach applies to the Ayia Irini figurines adding a quantitative element to find technical characteristics attributable to common hands or workshops. With respect to the traditional approach of Morris and Alexandrou, my work with automatic and quantitative comparisons gives life to unsupervised groups based on similarities.[268]

Significantly, the methodology developed for this research allowed for obtaining novel classification patterns and identifying specific individuals' hands/workshops in the sample of the figurines examined. Such a sub-division is something that, more or less unconsciously concerning the meaning, Gjerstad noticed during his study but that decided to neglect in favour of bigger classes: 'A minute classification of the overwhelming mass of the statuettes, with respect paid to all the typological difference as regards the technique, shape, representation, etc., would comprise more than fifty

[267]Although the approach is qualitative, the author tried to quantify the elements to compare them.

[268] In practice, the algorithms automatically recognise the primary and secondary elements.

types' (Gjerstad et al. 1935: 785-786). The obtained result is partial due to the sample size; the extension of the approach on the whole assemblage (and ideally on other productions of the island) will allow us to test the results.

5.2 Quantitative geometric classification and archaeological interpretation of the results

As presented in Chapter 4 (p. 140), several questions arose on how the proposed approach can help identify, compare and classify features that can give information about the production of the figurines under-study. After identifying specific measurements representative of those features, we carried out several 3D geometric experiments on the entire shape and specific parts of the figurines. Not all the experiments were helpful or fully descriptive for the interpretation and classification aims, such as the automatic geometric analysis applied to the entire figurines' heights. In those cases, we can only excerpt partial archaeological results even if there is efficacy in technology. Further developments would be needed, but this research's general scope and time constraints did not allow such an implementation. Depending on needs, we can always manually and automatically extract data from any parts of the 3D digital replicas and run classificatory and interpretative analyses.

Automatic classification according to production technique

Nevertheless, the method applied to the entire figurines' height has allowed automatic identification of the lower part of the Ayia Irini human figurines' bodies thanks to their tubular or -more or less flared - cylindric shapes (see section 4.1). The application of descriptors (e.g., Roundness and Eccentricity) on the automatically identified area appeared very effective for classifying the material according to its production technique. The quantitative analysis automatically discriminates the sampled figurines according to their production technique with high precision. It demonstrates the presence of two big groups of small terracottas within the sample: the handmade and the wheel-made (Figure 5.3). Moreover, comparing the quantitative and automatic analysis' results with the classification operated by the SCE proves the validity of the proposed methodology. Naturally, as described in the Ayia Irini material, the production technique used for the figurines is not a revelation: the knowledgeable eyes of the SCE archaeologists already defined the techniques used to produce the figurines and divided them into different groups. Therefore, it might seem that such an analysis is redundant or not necessary at the archaeological level. But no, this step helps solve primary archaeological doubts about production techniques of clay figurines. Many archaeologists agree that we need holistic and standardised applications of technology to support the interpretative process in coroplastic studies (see note 177). The automatic analysis proved that it is possible.

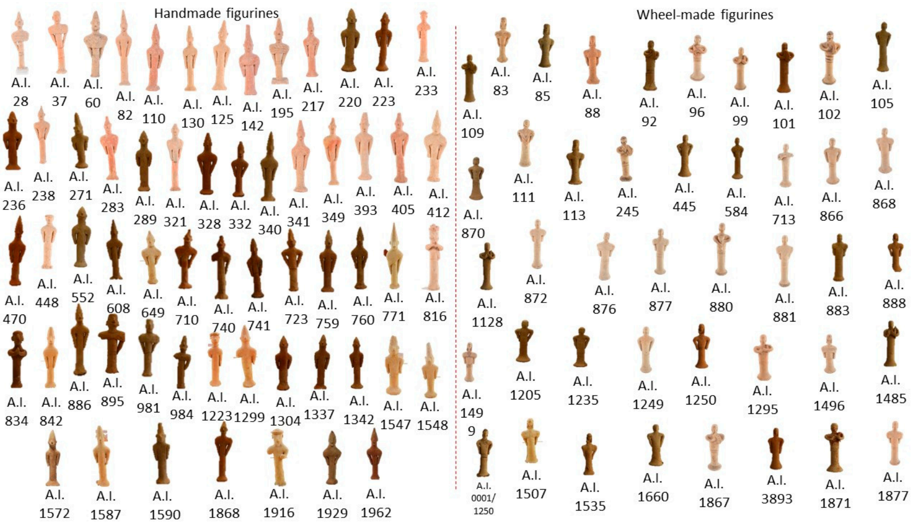

Figure 5.3
The two groups of statuettes as automatically divided by the quantitative analysis (Vassallo©).

Sub-grouping according to level of experience

The integrated descriptors allowed speculation on production methods and technical experience levels. For instance, the automatic identification of the tubular part on the hollowed statuettes (attributed to the wheel-made group) allowed the calculation of the material's width. Thus, the clay's homogeneity -or its variance- expressed the artisan(s) ability to produce those statuettes. Computation shows that clay thickness is stable throughout the sample (approximately 0.4-0.7 cm), with relatively constant values (Figure 4.8).[269] Thickness, apart from a few cases, shows a high degree of precision and uniformity in processing the clay and construction, demonstrating a high technical experience: those who made these statuettes certainly had a high level of mastery of the lathe.

[269] The clay thickness variations are in the order of millimetres. Although is manual work (even if assisted by the wheel) presents a very high precision.

Similarly, straightness and symmetry of almost all the wheel-made statuettes show high dexterity. The bodies, from the base to the neck, are accurate and well-built, appearing straight and symmetric, regardless of accessorising elements. In most of the figurines, the only element that does not follow the symmetry and axiality of the bodies is the head position. Such evidence possibly suggests collaboration among differently experienced artisans, perhaps a master and an apprentice working on various figurines or different parts of the same.

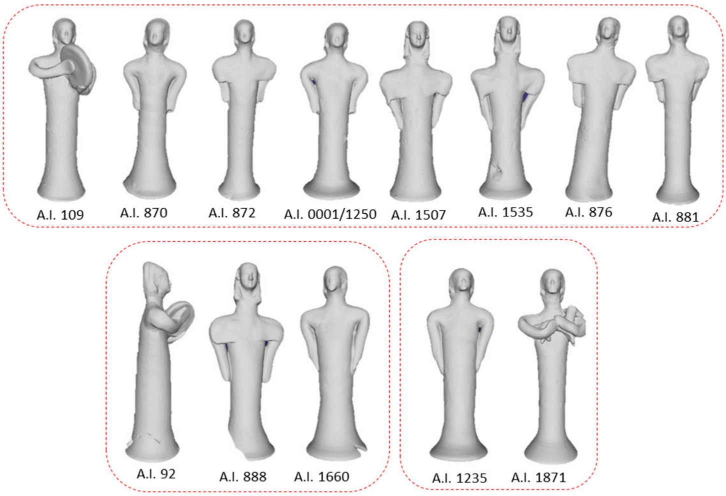

Figure 5.4
Lower level of expertise groups as determined by the Roundness computation (Vassallo©).

The analysis allowed identifying additional elements attributable to different experience levels or different hands. The automatic analysis further grouped the wheel-made figurines based on some inaccuracies in the structure. Thirteen figurines are automatically clustered together (Figure 5.4). Close observation confirmed that six of the artefacts had modelling problems (A.I.109, A.I.870, A.I.872, A.I.0001/1250, A.I.1507, A.I.1535, A.I.876[270] and

[270] The figurine A.I.876 is also extremely lopsided respect to the tubular body's barycentre with an inclination of around 15° respects to the central axis, which, nevertheless, still allows it to remain standing and stable. In general, some arrangements, such as the stability or other elements measurements (e.g., the arms), have been made so that the statuette appears as a final fairly well-done product.

A.I.881), for two to imprecisions in the manufacture (A.I.1235 and A.I.1871) and for three to damages (A.I.92, A.I.888, and A.I.1660). Although the analysis has automatically highlighted issues, it needs further improvements to determine the nature of the imprecisions.[271] As in any pottery workshop, there are well-made and poorly made products for sale; in these cases, the existence of "seconds" may reflect information about the buyer and not the artist. Nevertheless, beyond this aspect, it seems plausible that the identified issues might also relate to the level of experience of the maker. A poor-quality artefact does not exclude the possibility of an apprentice with lower experience and knowledge making the "seconds".

To summarise, the combined analyses of the wheel-made figurines possibly suggest that the artisan(s) had skill and experience, resulting in differentiated, high-quality work.

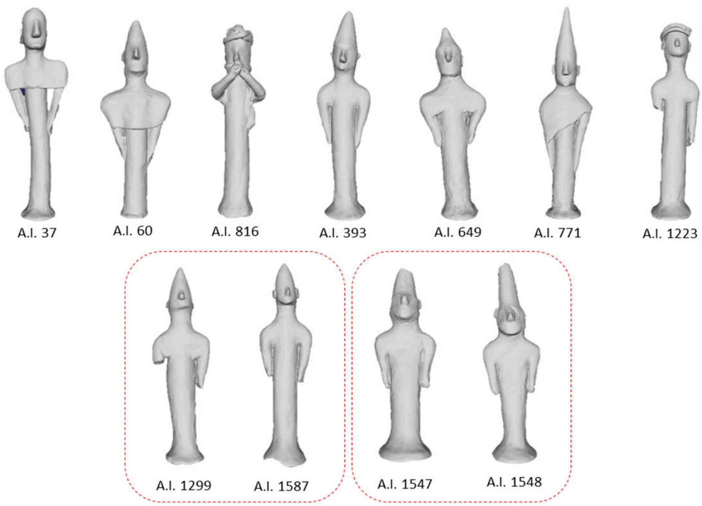

Figure 5.5
Higher level of expertise groups as determined by the Roundness computation. In the red rectangles, the two pairs of figurines also show qualitative similarities of 'primary' or 'secondary elements' (Vassallo©).

For the handmade statuettes, the integrated computation shows a more variegated result. Eleven artefacts show a 'higher' manufacture level (A.I.37, A.I.60, A.I.393, A.I.649, A.I.771, A.I.816, A.I.1223, A.I.1299, A.I.1547, A.I.1548, and A.I.1587). Within this group, two similar pairs of figurines

[271] A check is needed to address this issue.

(A.I.1299 - A.I.1587 and A.I.1547 - A.I.1548) show qualitative similarities of those ‘primary’ or 'secondary elements'[272], which returns us to Gjerstad’s Reference-Figurines and the suggestion of common hands (Figure 5.5). In this regard, the computation placed three figurines (A.I.37 e A.I.60 e A.I.816) in a group that Gjerstad and Fourrier put in two groups. This result shows a higher level of manufacture for these statuettes and that qualitative grouping is inconsistent (Figure 5.6).

Concerning the remaining handmade figurines, the calculation tends to show some production inaccuracies, such as problems of stability due to lack of straightness in relation to the barycentre (A.I.321 and A.I.710) or slightly asymmetric positions that make the statuettes lean either towards the front either towards the back, but all able to stand (A.I.405, A.I.233, A.I.448, and A.I.608). The rest are straight and symmetrical (e.g., A.I.82, A.I.217, A.I.130, A.I.340, A.I.341, A.I.289, A.I.236, A.I.740, A.I.349, A.I.393, and A.I.816).

In sum, the results on the handmade figurines highlight a more variegated situation with possible different levels of experience. Those different levels reflect in the sub-groups of statuettes that present qualitative similarities attributable to common hands.

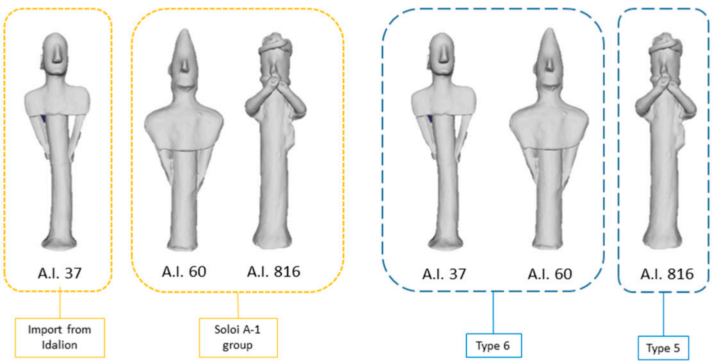

Figure 5.6
Qualitative processes result in different classifications. Yellow indicates Fourrier. Blue indicates Gjerstad (Vassallo©).

[272] Secondary elements include the rendering of the arms, the shape of the nose and the characterisation of the hands.

Crafting signatures and work standardisation

The 3D digital analysis tends to demonstrate the presence of production patterns such as specific clay's rendering, working/crafting traces, and work/product standardisation in creating the studied figurines (see section 4.1).

Specifically, curvature-based methods (p. 158 *et seq.*) helped enhance the surface 3D morphology. This enhancement allowed me to effectively identify and measure constituent parts to gather more information on the creative process and to shed light on the *chaîne opératoire*.

The technique and the mode of production of the small human figurines are commonly known. Nevertheless, surface curvature analysis helped identify invisible joints and parts to have 'diachronic' information about all the production steps of all artefacts.

The analysis of the wheel-made figurines demonstrates a production sequence that foresees the creation of the head with mould, the small arms' cylinders with hands and the body with wheel, and, finally, the assembling of all the parts. The analysis run on the handmade figurines supports the 'snowman' technique, where artisans model from one piece of tubular clay, manipulating a head from the top and arms from the sides. However, the digital analysis uncovered examples where arms and other elements were attached, suggesting a slightly different technique. Particularly, this seems to appear on those figurines (e.g., A.I.28 and A.I.37) attributed by Gjerstad through "reference-figurines'' to the Type 6 and, with a similarity approach, attributable to the Fourrier's "imports from Idalion" group. Therefore, the analysis confirms the presence of a different group characterised by a slightly different technique than Type 5 (possibly also originating from a different area?) and the validity of the Gjerstad system to identify, as in this case, another workshop/hand.

The lack of breaks or fractures at the figurines' joints within the sample examined suggests a quite good level of knowledge/experience in producing and assembling the parts, which probably happened when the clay was still wet to avoid breaks and guarantee a stronger adjoining (Alexandrou 2016: 73-74; Alexandrou & O'Neill 2016: 102).[273] In general, the 3D digital analysis of the surface shows a well-done smoothing of the parts to avoid traces of the attachments, elude detachment and make the joints stronger (also covering and giving them attire's shapes).

The analysis also witnessed a pretty good level of the figurines finishing and various working signs. The 3D surface analysis confirms that Ikosi (1992: 36) already observed that the artisans might have used tools capable of

[273] When missing, the arms are broken at different heights and never at the joint with the body.

smoothing the surface and eliminating defects in the working process (even on the less elaborated statuettes). On the one hand, this procedure covered exterior imperfections, supporting the hypothesis of careful attention to the final results.[274] On the other hand, it also covered signs that could be useful to identify specific hands or any working process, such as the fingerprints identified on some statuettes (A.I.83, A.I.99, A.I.111, A.I.877, A.I.1295, and A.I.1496 –actually only wheel-made figurines!). Unfortunately, since these fingerprint results are limited and partial, we could not use them at this research stage: other instruments might provide more detailed information on this aspect and run comparisons for the identification of common hands.

Curvature analysis shows that wheel-made statuettes present a uniform surface treatment on their front and back. On the other hand, a large majority of handmade statuettes differ from front to back: artisans rendered the backside roughly as though it would not be seen. Similarly, decoration is absent from the backsides. This pattern suggests that the artisans created these statuettes to place them in a sanctuary and face the front.

The surface's 3D morphology enhancement helped identify the constituent components of the statuettes so we could semi-automatically extract their related measurements and patterns (Scalas et al. 2018: 258).

The results show that measurements of parts of wheel-made figurines remain relatively constant, demonstrating a need for the final product to measure approximately 20 cm. The base diameter is marginally variable due to hand production. Differences in measurement relate to changes in body parts (observable also at the qualitative level). For instance, a group with long hair also shows taller heads (A.I.83, A.I.88, A.I.85, A.I.113, A.I.888, A.I.1250 and A.I.1507). Moreover, longer and shorter measurements of the joined arms possibly suggest that different hands prepared parts.

The homogenous relationships of some ratios demonstrate specific attention to creating human figures with standardised, stable and proportionate measurements. In addition, constant proportions coupled with the same qualitative characteristics may suggest production by a specific hand (e.g., A.I.881, A.I.872, A.I.883, and A.I.877). Thus, the analysis proves the presence of the same hands following a standardised working process: individuals from a common artisanal environment might have created these statuettes following some construction rules.

[274] In some cases, computer graphics emphasised on the wheel-made figurines the signs of the wheel's spins, which appear very regular and confirm a high level of expertise. Indeed, in some cases, the internal traces of the wheel were not visible, as the artisan smoothed the surface to obtain a clean product free from working signs.

The existence of rules, proportions, and canons in creating statues is a well-known topic, applied to different periods, geographical productions, and diverse materials, and studied with different methods. Regarding the Archaic period statuary, several studies focus on Greek production. A cultural trend based on searching for mathematical correspondences only for some statues' body parts then moved to consider the entire human figure, but with discordant proportions' systems and solutions (Winter 1887: 223-239; Kalmann 1893: 14; Delbrück 1900: 373-391)[275], deduced either based on manual measurements or supported by technological methods (Guralnick 1976). These studies have mainly focused on big statues, small bronzes (Furtwängler 1890: 142), or medium/large statuettes (Weingarten 2000[276]), but they never focused on small figurines. Only a recent study, although not aimed at finding proportions and canons, focuses on the study of very small figurines (i.e., Egyptian shabtis). Whitford et al. argue that for their figurines, batch processing based on standardisation was far more likely than mass production (2020). Similar, the Ayia Irini objects suggest standardisation rather than mass production, particularly among the wheel-made and moulded figurines. Mass-produced objects have limited or no variability. The Ayia Irini objects share variants that suggest a workshop where artists possibly specialised in parts and followed some rules or standards.

The analysis run on the handmade figurines shows that the parts' measurements of these artefacts do not remain constant in all the specimens: that tends to demonstrate greater variety in producing these artefacts, partly due to the presence of hand process, but also to more operating hands. Nevertheless, for some of them (e.g., A.I.1342, A.I.552, and A.I.223), quantitative recurrent similar measurements corresponding to some qualitative characteristics can be recognised. For instance, some statuettes presenting the same head's height also have the same type of accessories rendering, such as short hat, long hat, truncated hat and turban (e.g., A.I.271, A.I.1590; A.I.1548; A.I.321 and A.I.349). This observation might seem obvious, but it points to a desire to create similarly shaped and sized objects, which might also indicate an individual or workshop reproducing specific types and characters, for example, an authentic headgear or specific

[275] Alongside this line of studies, there is also the proposal of a Greek proportions system of Egyptian origin -the modular grid of the second Egyptian canon (Winter 1887; Kalmann 1893; Iversen 1957: 134-147; Boardman 1964: 161-162) or the existence of different proportions schemas adopted by the various Greek artistic schools of the Archaic period.

[276] The author advanced that Minoan artists had developed a systematic geometric division of the human body to produce their statues derived, and with some variations, from the first Egyptian canon (Weingarten 20009).

personage. This theory supports Houby-Nielsen's suggestion about the relationship between ethnicity, social status, and arrangements of figurines (Houby- Nielsen 2016: 111-112).

The production technique identified for the majority of the figurines, obtained by rough-hew and eliminating pieces from the clay lump, demonstrates that only one person might have prepared each statuette, and the possibility of collaborative work with the division of labour, as hypothesised for the wheel-made group, must be abandoned.

The ratios' analysis shows the intent to create human figures with proportionate measurements and reveals quantitative similarities in groups of figurines that also present qualitative similarities (e.g., A.I.1590, A.I.271, and A.I.1548), such as the same body and head/hat shape, same arms rendering, and similar decorations. The stable proportions noted within some subgroups bring attention to the possible production by several hands following a standardised working process, at least according to the type of figurines to represent, resulting in qualitative and quantitative similarities.

In this context, weight also played an essential role in interpreting the production from a *chaîne opératoire* perspective. Many scholars contributed to comprehending the weighting system in antiquity (Petrie 1926). The weighing was a common practice, maybe not a standard procedure for every activity, but for sure, there is the attestation of such a process (Hafford 2005). For instance, in a workshop, it makes sense to imagine weighing with hand balances: we can imagine the artisan adding the increasing load on one side to balance the load of the other side to assess easily and quickly the material quantity needed for the production of an artefact. Similarly, not involving the use of scale/weights, it is also easy to imagine how the eye of an expert artisan might have prepared the exact amount of clay not to have waste in the production of specific products (e.g., a certain amount of clay to produce shapes of a specific height).[277]

The artisans might have used a similar procedure to produce their figurines. It is plausible that various factors affected these products' economic value. The ancient writers did not report the value of these objects, so their cost is lost to history. Uhlenbrock (2016: 9) suggests a link between the figurines' values and the material, the iconographic representation or the possibility of handling them (e.g., lighter figurines might have been more expensive than the heavy ones).

[277] The procedure is still in use in some modern artisanship. For instance, pizza makers precisely weigh their small doughs to have homogeneous and economically convenient products.

Naturally, for larger figurines, the presence of decorations or embellishments with more expensive or imported pigments must impact the price. What then of small figurines with simple or no decoration? It is reasonable to assume that these were cheaper than other statuettes, for instance, the larger statues dedicated to the sanctuary. Lastly, it is probable that also the time spent on production could contribute to their value.[278] According to Ikosi (1992), the Ayia Irini single-man human figures standing in a frontal position with arms along the body, classified by Gjerstad as Type 5-6, were very common and probably cheap to buy, especially the not painted version, for the offer at the sanctuary.

Calculating the figurines' weight shows a relatively uniform production, and the handmade statuettes are less uniform than wheel-made ones (Figure 4.17). Due to the limited number of objects analysed, it is misguiding to suggest evidence of existing specific weight units for producing those figurines. Nevertheless, such homogeneity confirms the idea of possible standardised production and the presence of a pattern, suggesting homogeneity in using the raw material related to the *chaîne opératoire* discourse. Regarding the analysis of the handmade figurines, similarities are notable according to sub-groups previously identified with the other extracted measures, underlining a possible diversification of the production due to more hands.

Standardisation for the wheel-made/moulded statuette can be inferred. Moreover, the figurines sampled present some characteristics (e.g., constant values of several parts and measures) that suggest the presence of rules and similarities and, consequently, of common crafting work organisation. Such analysis proved the presence of manufacturing standardisation. The measurements show stability or no significant variations and tend to demonstrate the presence of fixed rules and ratios in the artefacts' production. The obtained results demonstrate the presence of stable and homogeneous measurements in the several parts that make incline to think of the existence of rules and set ratios (at least some) in the construction of the figurines and consequently of a type of standardisation in the production (attributable to the same hand/artisanal environment).

[278] In this case, Uhlenbrock (2016: 10) underlines how the evidence from votive deposits suggests a sort of mass production to obtain a high number of artefacts with high profit, low expenses, and fewer efforts. She supposes that the artisans sold even low-level products (badly fired and ready to break) for the only dedication in the sanctuary.

Automatic classification according to figurines shape analysis

So far, the analysis focussed on the entire structure of the figurines and how the various parts relate to each other and the whole in the search for levels of experience, work standardisation, and identification of patterns associated with production and artisans, useful to identify and group them. Specific parts of the figurines can also play an essential role in this research. For instance, the 3D geometric analysis of the heads supported the archaeological and typo-technological interpretation of the figurines. In Chapters 2 and 4, we underlined that the case-study material raises further archaeological sub-questions connected to their production (mould and handmade) and if a digital assisted analysis can help to provide new insight into their interpretation/classification. Geometric analysis provides insight into the number of moulds used and the relationships between moulds and statuettes. In turn, this analysis suggests production patterns and sub-groups for handmade heads. Moreover, the identification of similar features leading to the same hands also adds information to the "relative" chronology of the groups (a "first and after" paradigm, intra- and inter-clusters).

These experiments employed a procedure that automatically supports the classification work based on criteria that are non-subjective or chosen in advance and on quantitative information.

Hand modelling is the oldest and most used technique in antiquity. Over time, the procedure becomes more complex, throwing clay on a potter's wheel to produce some figurine elements (usually the body). Besides, the moulding introduction in the Levant and the Greek world in the 7th century BC and its generalised use in the 6th century BC (Biers 1994: 511-512; Muller 2000: 91-106) increased the possibility of having a variety in the production, also allowing the combination of the various techniques.[279] Initially, moulding consisted of a cast for the front and often a simple shape for the back (Yon 1981; Caubet et al. 1998: 100-103; Caubet 2009: 47), and it brought technological progress in the production of clay objects, allowing the higher production of several similar objects to respond to the growing request.[280] In the history of coroplastic studies, archaeologists identified pieces produced by the same mould: the presence of the same characteristics,

[279] The first simple mould process is supposed to start in Mesopotamia and southwestern Iran at the end of the third millennium BC

[280] See Burford (1988: 379-381) for what concerns the topic of mass production and moulds.

such as "identical"[281] dimensions or the same fault of the mould, is proof of their similarity hypothesis. Unfortunately, this is not enough to completely understand a more complicated manufacturing pattern. Indeed, a moulding production pattern may involve two possible different but connected procedures. The first one starts with mould production and baking: successively, the artisans can produce and bake from that mould several figurines. According to this procedure, the same artisan could create (possibly with the same clay) other figurines. The second procedure instead starts with the figurines to create a new mould. After the creation and firing of the figurine as a model (called "archetype", "patrix", or "prototype"), the artisan obtained the new mould by pressing wet clay onto it (Muller 2000: 91-106).[282]

According to Arthur Muller, the fabrication of moulds from artefacts increased production, thus giving rise to the second generation of moulds and over-moulded generations of figurines (Muller 1997a). The moulding process and its derived mass production requires, quoting Muller, "*neither imagination nor particular know-how*" and even "*entrusted to children*". Most probably, only creating the modelled prototype on which the first mould is taken requires a perfect mastery of clay's work and identifies the master of the workshop (Muller 2000: 91-106).

Those new productions could have been similar but different in size, adding a new variable to the material's interpretation. A smaller size will characterise the figurines created from these new moulds. The figurines' dimensions might decrease increasingly if this procedure of the re-creation of the mould is done repeatedly (Nicholls 1952: 220). This change could happen because the clay shrinkage after baking (or hardening in the air) can affect the mould and the figurines, which could be different in size to the matrix and the archetype.[283] Each over-mould

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[281] Based on the previous chapters' discussion, the term "identical" is in brackets to underline how the traditional studies, even if based on measurements, are linear measurements that can be misinterpreted.

[282] Moreover, from the prototype, it was also possible to create only some parts that, combined with other moulded parts, could give birth to new different types (see Jastrow 1941:1-28; Nicholls 1957: 217-226; Blondé & Muller 2000:437-463). Any figurine can become the archetype of a new type: adding or modifying some details and creating a new mould gives life to a new type generated by the previous one. The addition of features testifies the will to diversify the standard production

[283] Shrinkage can depend on clay composition, its preparation, and its production technique (e.g., the thickness of the object's wall), but this variation alone is not sufficient to assume a division into generations. Generally, it is observed that the clay shrinkage amounts to about 9-10% and occurs more during drying in the air than during firing (Nicholls 1952: note 21).

(*surmoulage*) is smaller than its model, and each print is smaller than its mould (Muller 1997a: 372, fig. 21).[284]

For this reason, Nicholls (1952) underlines as a study of the mould "series", looking at degradation in size and details created by the use, could be of chronological significance. We can deduce such elements from analysing the change in size regarding the archetype (when it is possible to have this information) or among the artefacts, giving an idea of the degradation from the parent mould or between statuettes possibly produced with that mould (see also Ikosi 1993: 29). The exact measurement of the same type's different copies can help reconstruct the chronological sequence. The outlines will appear more and more blurry as continuing with the process.

In this context, shape analysis of heads found similarities between those body parts and helped address the research questions (Chapter 4).

First, the automatic analysis of heads confirmed the central subdivision of the material into two groups according to their production technique, demonstrating the use of moulding for the heads of the forty-three wheel-made figurines and the handmade process for the remaining sixty statuettes (cf. Figure 5.3). That is an important result, responding to the need for an approach to assist archaeologists in automatically recognising the use of moulds in the production of figurines.

The automatic analysis demonstrates that at the moment, in the research sample, it is possible to quantitatively identify three different moulds: one for the "short hair" and two for the "long hair" heads (Figure 5.7). In general, there are no sufficient elements to contradict the use of five different moulds for the production of the Type 7 heads, as suggested by the SCE archaeologists. The inclusion in the sample of all the artefacts attributed by the SCE to Type 7 and the insertion of all the statuettes counted in the so-called "small human idols" could provide information in the presence of additional moulds. Indeed, it is worth stressing that also, with the dataset available, a solid conclusion has been reached. The automatic shape analysis was able to sharply determine the use of mould from manual production, providing a valid solution to the issue raised by many scholars in archaeology about the difficult recognition of many artefact production techniques. Moreover, the results obtained in identifying three different shapes attributable to related distinct moulds prove the method's efficacy.

[284] Nevertheless, according to Muller (1996: 33-34), the change is not due to the mould itself that, in his opinion, does not wear out, but it is because of the repeated reproductions of the archetype.

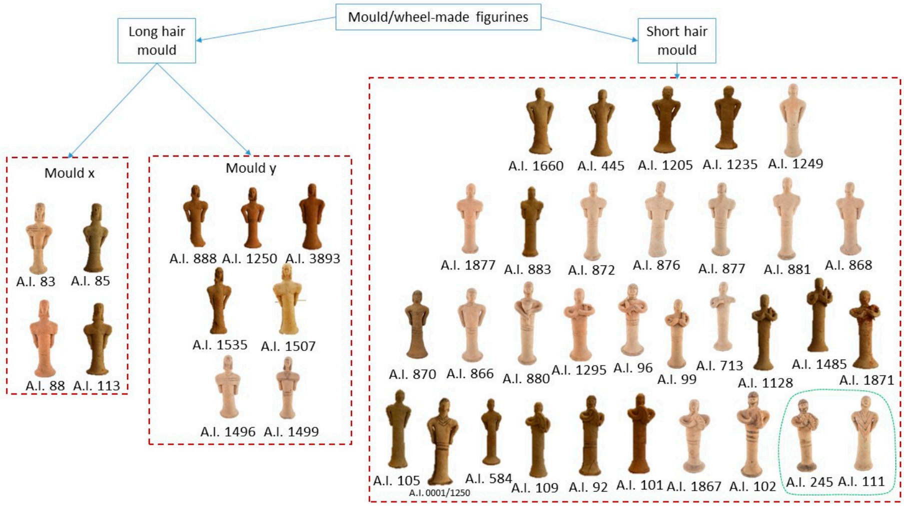


Figure 5.7
Classification of the sampled figurines included in the SCE Type 7. The novel sub-classification with 3D shape analysis transparently associates figurines to each mould.

For the "short hair" heads, we can affirm the use of one mould to produce thirty-two figurines' heads. The automatic analysis demonstrated the use of two different moulds for the "long hair" statuettes. Specifically, in the sample of this research, it appears that four statuettes were created with a *mould x* (A.I.83, A.I.85, A.I.88, and A.I.113), and seven statuettes were produced with a *mould y* (A.I.888, A.I.1250, A.I.1496, A.I.1499, A.I.1507, A.I.1535, and A.I.3893).

In this context, another exciting element came from the 3D visual analysis of the moulded heads: the different locations of the figurines in several museums did not allow spotting.[285] The identification of a not very visible small hole on the heads' top of the four figurines A.I.83, A.I.85, A.I.88, and A.I.113 confirms the appurtenance to the *mould x*. The analysis demonstrates that the mould employed was the same because it had a fault/characteristic that left traces on its related statuettes. Furthermore, this quantitative result suggests creation during a close chronological period, as there are no differences in measurements among these features.

[285] Two museums (CM and MM) host the figurines attributed to the *mould x*, and three museums (LU, MM, and CM) conserve the figurines attributed to the *mould y*. It is clear that a whole study of the material is seriously prevented in this situation, and only a digital analysis as the one proposed overcame the cited obstacle.

Generally, regarding the production of these forty-three figurines, the 3D analysis validates using single front casts for moulding the heads of the three identified different shapes. The flat but still variable back part of the heads, and the lines of pressure evident on the "long hair" items, suggest the use of frontal moulds, as also testified in other nearby areas of the island (Ikosi 1993: 14).[286]

The slight differences identified on the items by the shape analysis and 3D visualisation are due to possible diverse causes: for instance, different pressure of the clay in the mould during the creation, shrinkage, degradation of the artefacts or overmoulds no longer producing shapes with clear and sharp details and indicating in terms of relative chronology an earlier or later production. According to Fourrier (Fourrier 2007: 91), for what concerns the moulded head figurines, people imported them directly from Kition or passed through Lapithos, and from them, new moulds were created for the production of new artefacts. That would explain why some statuettes present faded face features' incisions due to the umpteenth over-mould.[287]

Unfortunately, only specific quantitative comparisons among the heads could provide additional information on these differences.[288] Nevertheless, combining diverse information allows us to propose some chronological relations, such as contemporaneity and sequences (see further in this chapter).

Moreover, similarities and differences in rendering the secondary features (e.g., arms, shawls, and accessories) provided information about the makers. As Ikosi (1993: 31) underline, such elements can be of interest for identifying different coroplasts: especially in the same "series" of statuettes. They could hint at the different or common "finishing touch" operated by an artisan.

Specifically, the digital analysis suggests the presence of more than one artisan for producing the wheel-made/moulded statuettes, as already assumed

[286] Other finds, like those from the Kythrea sanctuary, prove the use of frontal moulds (a single mould with the back part differently treated) for the creation of small terracotta figurines.

[287] Fourrier also mentions that, for that reason, black pigment facial elements were added to cover the imprecision. Nevertheless, from a technological point of view, rendering facial features with paintings requires a high level of detail and care in applying tiny elements. In some cases, this is not done with attention, and the painted elements appear even grotesque, so it sounds strange that the artisans added more inaccuracy to the already present moulding's inaccuracy.

[288] The clustering analysis run on these figurines is the best solution tested within this research to define classes of similarity automatically. However, the quantitative results obtained cannot determine a chronological sequence in the production within the sub-groups identified. We need other tools and experiments that the time frame and the broader scope of this research prevented to test and that we will possibly develop in the future, likely having at disposal the 3D models of all the assemblage figurines.

by comparing their measurements. Moreover, these similar secondary features appear to be transversal to the defined sub-groups. Notably, all four items created with mould x present similar features. Combining all these secondary elements with the previous quantitative results suggests a high percentage of contemporary production by the same individual.

Some of the secondary features of the mould x group also appear within the group created with mould y. In contrast, other figurines of the latter group share similar secondary features with the figurines created with the "short hair" mould. From a chaîne opératoire and technical point of view, these similarities and differences tend to suggest the presence of two (maybe three) artisans in a shared artisan environment, possibly even a collaborative work involving a sort of differentiation in the preparation of the parts (e.g., presence of novices creating only specific parts, i.e., the arms?). Furthermore, in some cases, it is possible to identify the secondary elements on figurines with sequential identification numbers (e.g., AI 872, AI 876, AI 877, AI 881), which underline the placing in the same area and layer and, therefore, suggest a possible contemporary deposition and production by the same hands.

Such results partially confirm and integrate those of Ikosi on clay (1991-92: 274). Her proposal, unfortunately not transparently explained, of the identification of two masters for the production of all different sizes terracottas seems to be incomplete and not taking into consideration the possible stylistic/geographic provenance considered instead in Fourrier's work. The sub-division so far here delineated in the wheel-made/moulded group and that obtained in the handmade one demonstrates, in fact, a more variegated situation.

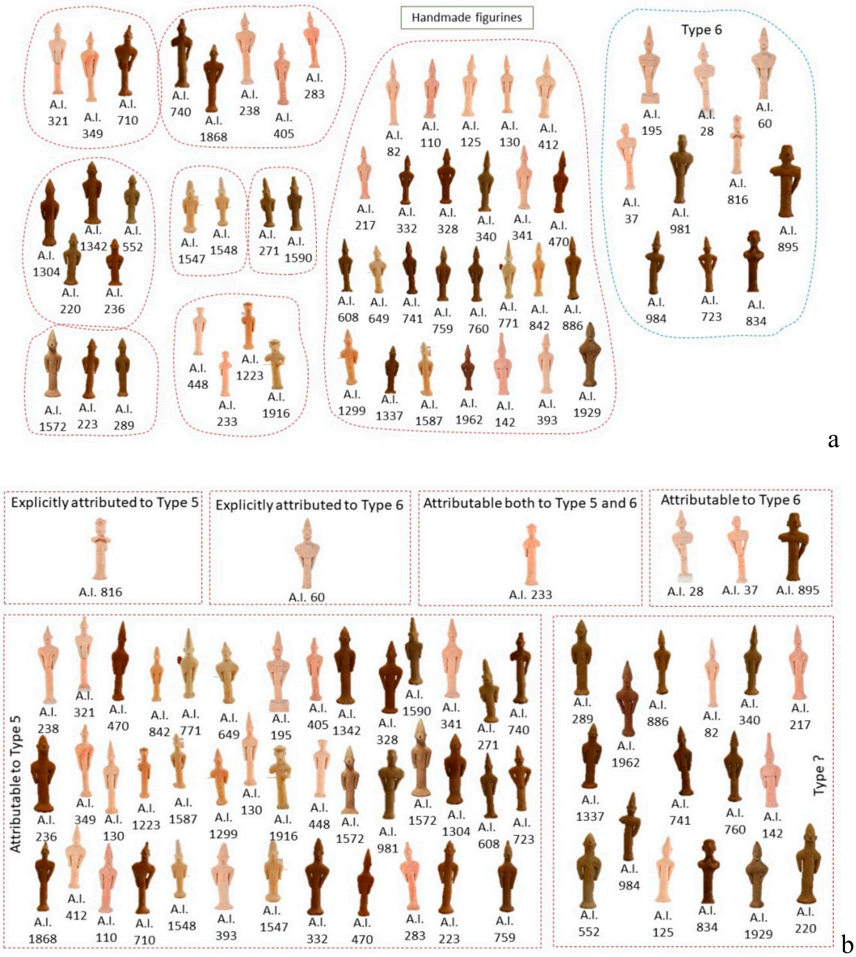
Although with less precise results than the previous group, the 3D shape analysis applied to the sixty heads of the handmade statuettes highlights similarities that tend to demonstrate the presence of sub-groups possibly attributable to different hands and kinds of productions.

The shape analysis reveals the constant presence of figurines' sub-groups (Figure 4.29), significantly characterised by the same primary (e.g., "long hat", "short hat" heads, and "truncated hat" heads) and secondary elements, which we can connect to the hand's signature and therefore be necessary for interpreting the production.

The 3D analysis results and their comparison with the previous classificatory studies (Gjerstad et al. 1935; Fourrier 2007) highlighted some aspects. First, the investigation tends to confirm the presence of two macro groups. From Fourrier's analysis of figurines that also fall within the sample of this research, whose stylistic characteristics led her to propose a specific geographic provenance that here is not discussed, and the one proposed by Gjerstad, it seems that the scholars generally come out with a similar macro subdivision ("Soloi A-1" and "Soloi A-2" = Type 5; "imports from Idalion" = Type 6). Nevertheless, comparing the two qualitative studies, some inconsistencies emerge, such as the same attributions of some statuettes to different groups due to no clear-cut criteria definition. The element that they could not identify, enhanced instead by the 3D analysis, tends to demonstrate that the figurines present some differences in the manufacture that help to divide them into two different groups: the snowman technique for the Type 5 and the pieces' attachment (i.e., arms) for the Type 6. Such a result determined the first main subdivision of the material and tends to demonstrate the presence of two possible different workshops (Figure 5.8).

A novel classification after the 3D digital and quantitative analysis of the small handmade figurines sampled for this research can be summarised as follows. With some differences with respect to qualitative studies, the quantitative analysis attributes to the group identified by Gjerstad as Type 6 and by Fourrier as "import from Idalion" nine figurines and tends to demonstrate the production by the same workshop (A.I.28, A.I.37, A.I.60, A.I.195, A.I.816, A.I.834, A.I.895, A.I.981, A.I.984, -possibly A.I.723).

The automatic analysis tends to cluster the remaining figurines into sub-groups characterised by the same criteria (e.g., squared head and rectangular nose, long hat). The 3D visualisation enhancement of the production technique makes to incline of the attribution of these artefacts to the other main group identified by Gjerstad as Type 5 and by Fourrier as the "Soloi" group(s). Although with less accuracy with respect to the moulded heads, the automatic examination determines some sub-groups. Specifically, the analysis shows a bigger group of around twenty-four figurines characterised by similar features (e.g., "long hat"). Other separate and quite distinct sub-groups appear: for instance, the one constituted of five/eight statuettes (A.I.236, A.I.220, A.I.1304 A.I.1342/ A.I.1572 A.I.223, A.I.289 and A.I.552) all characterised by the same short triangular face, or the one constituted of four figurines (A.I.271, A.I.1547, A.I.1548 and A.I.1590) characterised by a trapezoidal head, and that remains very much defined. Finally, the analysis identifies the presence of a group of figurines (A.I.321, A.I.349, A.I.405, A.I.710, A.I.740, and A.I.1868), characterised by very similar "truncated hat" head. This group is particularly interesting for interpreting the production of the statuettes which belong to it since the parallel analytical investigation on the statuettes' production pattern (see further in this chapter) shows the identification of traces that confirm the geometric sub-classification (Vassallo et al.-in preparation). In general, the quantitative subdivision highlights qualitative similarities that most likely prove the common production by different hands. Moreover, the digital approach proposed here confirms what, although complicated by the traditional method based only on visual recognition and subject to mistakes and inconsistencies, was Gjerstad's brilliant intuition in using the “reference figurines” system, unfortunately not entirely (or explicitly) used to determine production interpretation and attribution to the same hands.



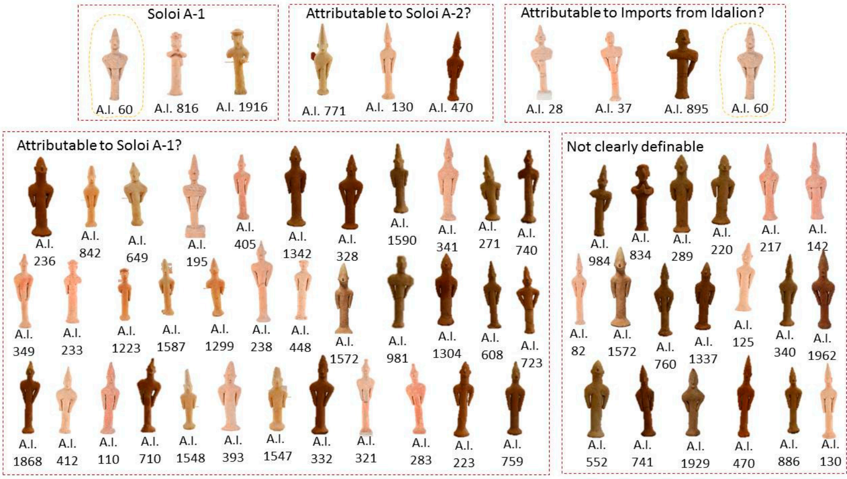


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Figure 5.8

Novel sub-classification of the handmade figurines (a). The comparison with the Gjerstad classification (b) and the one deduced from Fourrier's groups (c) shows the differences and possible inconsistencies in the solely qualitative attribution to classes (Vassallo©).

5.3 Physico-chemical results, interpretation of the material provenance and production patterns

Within the proposed *chaîne opératoire* approach, several archaeological questions led the analytical investigation towards characterising the material surface to identify quantitative features useful to their interpretation and classification. Decorations and pigments, together with the mode of manufacture and production, contributed to that scope.

The non-invasive analytical investigation confirmed the presence of colour traces. It characterised their chemical composition (Table 5.2), demonstrating that they were voluntarily applied to decorate the surface with specific patterns.

The visual macroscopic observation of the clay surface confirmed the presence of slip (diluted clay), as reported by Ikosi (1992: 36), on the surface of almost all of the statuettes included in the sample (103 figurines). The presence of some drips due to slip wash suggests the use of small tools, fabric or fingers to smooth the surface and adjust it from possible defects, being careful not to leave finger impressions, which are very rare and slightly visible. The microscopic observation confirmed the slip presence on all the six figurines of the Cyprus Museum analytically investigated. This presence shows that in the CM small sample, there is always an association of slip and colour. However, we cannot say there was always colour when in presence of the slip. Small statuettes were likely prepared with slip and decorated at the end at the request of a worshipper or according to the price. Indeed, in some cases, the fall of slip's parts suggests the possible presence of both (see further in the chapter). Evidence indicates that colours were applied after firing (Törnkvist 1970: 110, citing Higgins 1952: 5, 7).[289]

Table 5.2
Summary of the colours identified on the statuettes conserved at the Cyprus Museum and results of their chemical analysis.[290]

Inventory Number	Visual Examination	Type of Analysis	Colour	Pigment	Notes
A.I.111 	Black colour Red colour	Microscope, XRF	Black Red	Manganese black Iron red	
A.I.245 	Black colour Red colour	Microscope, XRF	Black Red	Manganese black Red ochre	
A.I.321 	Black colour? Red colour?	Microscope, XRF	- Red Yellow	- Iron red Iron yellow (jarosite or natrojarosite)	Black (organic)

[289] It is possible that painters were in charge of decorating the statuettes, but it cannot be excluded that the coroplasts themselves were completing the work.

[290] For a comparison with pigments found and analysed on Cypriot Archaic statues, see Gasanova et al. 2017; Gasanova et al. 2018.

Inventory Number	Visual Examination	Type of Analysis	Colour	Pigment	Notes
A.I.349 	Black colour Red colour Yellow colour?	Microscope, XRF	Black Red Yellow	Manganese black Red ochre Iron Yellow ochre	
A.I.405 	Black colour? Red colour?	Microscope, XRF	- Red?	- Iron red	Black (organic)
A.I.816 	Black colour Red colour	Microscope, XRF	Black Red Yellow/orange	Manganese black Red ochre Orpiment	

The analytical examination provided information for the classification of the figurines and the interpretation of their production.

The chemical analysis revealed that all the CM sampled figurines present black remains but of a different nature. The majority (A.I.111, A.I.245, A.I.349, and A.I.816) have traces of black manganese pigment used for decorative elements of the attire (e.g., chiton, clothes' borders, hat) of the accessories (e.g., tympanon), and for facial features (e.g., beard, eyes, hair).

Two statuettes (A.I.321 and A.I.405) show a black colour of possible organic origin, identified as soot by Gjerstad (Gjerstad et al. 1935: 687). The extension of this 'contamination' on the two statuettes is quite large, covering A.I.321 mainly on the upper front of the torso and A.I.405 on the whole back part. No previous investigations on the firing procedures of the Ayia Irini statuettes have been carried out, but we can compare them with research on other material (Vaughan 1987; Alexandrou 2016: 86-89). Some studies attribute these black (or reddish) patches to the firing in pits, where lack of space and uneven heating caused an oxygen reduction. Moreover, they propose to use these elements to identify the specific firing technique employed (e.g., firing pits versus kilns) and attribute the figurines to a particular workshop or hands (Alexandrou 2016: 90).

The presence of these large black patches tends to suggest contamination due to fire proximity in an oxide reduction firing procedure. Moreover, the current digital shape analysis cluster both the mentioned figurines (A.I.321 and A.I.405) in the same sub-group, suggesting, consequently, contemporary production of the "truncated hat" statuettes by the same hand/workshop and possibly with the same firing technique.

Other elements tend to confirm the assumptions previously elaborated about the group. The physico-chemical analysis of the statuettes brought the identification of ‘new’ colour traces previously not mentioned in the Ayia Irini literature. A red area on the left shoulder and a large yellowish one on the right, both delimited by manganese black traces, were spotted on the A.I.349 figurine. The microscopic and analytical investigation allowed us to identify red ochre pigment on the front of the trunk, part of the left arm and the back of the head. We also found yellow ochre pigment traces, which suggest the pattern repeated on the right front chest and arm.

The analytical investigation revealed red iron pigment with yellow (jarosite or natrojarosite) on A.I.321. In contrast, only traces of red iron were uncovered on the A.I.405 statuette.

The high-resolution 3D visualisation highlighted the presence of pigments on another item (A.I.238), with traces of red decoration on the shoulders, black on the right arm (as to draw the sleeve of a tunic), and a small yellow spot on the left arm, recalling the decoration of A.I.349 and A.I.321. Moreover, for another statuette (A.I.283), also classified by shape analysis in the same group, the presence of a similar decoration can be highly probable: Gjerstad reports the presence of an undefined ‘colour’ (Gjerstad et al. 1935: 684), unfortunately now lost.

The 3D analysis revealed other elements aligned with the previously cited results. The arms' black lines and red spots indicate a chiton pattern on A.I.710. It also showed dropped slip areas (‘turned into red’, as reported in the literature), suggesting the presence of parts compatible with now-lost decoration (A.I.740 and A.I.1868).

The similarity identified in the decorations and pigments composition obtained by analytical investigations confirm the clustering achieved through shape analysis. This examination supports the same workshop theory – that these statuettes were produced and decorated following a specific decorative pattern, possibly by the same hand.

The three-colour-chiton discovery is crucial as it suggests a specific sub-group belonging to the handmade assemblage. The results are also significant for the archaeological interpretation of the Ayia Irini small statuettes production.

In her dissertation on Ayia Irini terracottas' dressing, Sylvia Törnkvist underlines that the artefacts are represented by the majority with long chitons or tunics. No further details are provided beyond the fact they are cylinders rendered using wheels or hands. She generally mentions that this specific rendering, similar to long chitons, might resemble the garments represented by Near Est statuettes and particularly by Assyrian reliefs, and the intention was to render worshippers dressed for a religious ceremony (Törnkvist 1970: 13, 19; Törnkvist 1972-73: 14-15, 20).[291] Specifically, according to Törnkvist, colours and painted lines on the small figurines, differently from the larger ones, were applied as ornamental designs without illustrating an actual specific chiton pattern (Törnkvist 1970:111; Törnkvist 1972-73:51-52).

The current non-destructive analytical results on the sampled figurines contradict her affirmation. The microscope and chemical investigation, coupled with 3D high-resolution visualisation, demonstrates a specific decoration pattern where the red and yellow areas, delimited by black lines, were used to create details of a particular tunic/chiton. The decoration, repeated on several statuettes, tells about the artisan's will to reproduce an actual chiton pattern, made of a specific combination of colours distributed in a particular order and shape, and distinguishing it from other statuettes' decoration. It seems that, with fewer details concerning the larger statuettes and statues, some of the small statuettes express through their decoration the religious culture of the Cypro-Archaic period, with different styles and foreign influences[292].

The non-invasive physico-chemical and 3D visual investigation results are particularly relevant. They suggest that, since there is not always an association of the yellow colour with red and black, it might be related to the type of decoration and the statuette typology. For instance, given the current

[291] Moreover, she mentions that some of the small figurines are also represented with a short mantle/shawl, wore in different ways: simply covering the shoulders, both on the front and the back and probably without the use of pins or fibulae, or on one shoulder maybe using pins similar to the Assyrian way. Although the author refers to the larger idols and the statues, where these features are detailed, the small idols present the same styles (Törnkvist 1970: 7; Törnkvist 1972-73: 8; Houston 1964).

[292] Vermeule (1974) proposes how the style and the clothing types of the Archaic Cypriote sculptures are a representation of the different ethnicity composing the society of the time, when three ethnic and linguistic components cohabit in Cyprus: Greeks, Phoenicians, and Eteocypriotes. Similarly, Ikosi (1993: 26, 73-74) proposes that some decorative garments often occurring in Archaic Cypriot sculptures in stone, ichnographically recalls Egyptian examples.

results, yellow associated with black and red is connected only to a specific group of handmade statuettes. It is not present on those wheel-made/moulded. For the latter group, the analytical investigation shows the combination of red and black pigments characterised by the same composition (iron red/red ochre and manganese black) and a similar decorative pattern (e.g., A.I.111 and A.I.245). These decorative similarities and the attribution to the same 'short hair' mould sub-group by the shape analysis tend to demonstrate a potential contemporary production by the same hand operating within the same workshop where several artisans might have produced similar artefacts (Figure 5.7).

However, the presence of a third pigment, such as yellow iron oxide (yellow ochre) found in association with the most commonly used colours (black and red), so far never been mentioned by previous studies about the Ayia Irini small figurines (and probably also to the remaining assemblage[293]), is particularly important. This discovery tells that yellow was available in the pigment palette of a specific artisan -or workshop- who created specific figurines among those found at Ayia Irini. Moreover, we cannot exclude a social or religious meaning based on pattern, colour and type.

Additionally, even more important, another figurine (A.I.816) presents a combination of the three colours beyond the cited specimens. In this case, a different, rarer type of yellow has been identified: the analysis points to arsenic (As) which occurrence, in a yellow pigment, indicates the presence of orpiment (arsenic trisulfide - As_2S_3) (Grissom 1986), a bright mineral known and used since antiquity.[294]

In an assemblage, beyond the artefacts' typological and stylistic analysis, the discovery of information connected to the materials' provenance (local or imported) for their creation can shed light on their classification and interpretation, besides the reasons and mechanisms behind it (Uhlenbrock 2016). In this context, identifying any possible imports or exploring the local production (by different or the same workshops) provides further information to the study. It follows that it is essential to know the pigment's history because it can help establish the artefacts' provenance and possibly date them (Szczepanowska 2012: 228). Nevertheless, identifying pigment provenance

[293] The colour could have disappeared either due to the extreme transience of this colour compared to the others, either to the cleaning treatment the figurines have been subjected to.

[294] The Romans called it auripigmentum since it was used to reproduce and recall gold. The mineral pigment is found in volcanic environments, often together with other arsenic sulphides (e.g., realgar - As4S4) and sometimes in low-temperature hydrothermal veins, together with some other sulphide and sulfosalt minerals.

can be challenging. The limitation of the instruments used, the lack of information about the geological compositions of the mines' areas (especially of the ancient mineralogical sources), or the ubiquitous nature of the minerals used to produce pigments in antiquity, are some of the explanations. For example, iron oxide minerals are prevalent throughout the pre-historic and classical world (Berry 1999).

Nevertheless, the presence of manganese black, iron oxides pigments and ochre (red and yellow) is compatible with Cyprus' geological formation. These minerals were available and commonly used on the island. Therefore, the finds of manganese black, iron red, and iron yellow pigments may suggest the use of local raw materials to produce the small figurines (Constantinou 1972; Gasanova et al. 2017: 542).

On the other hand, the complete absence of orpiment mines or deposits of arsenic-containing materials in Cyprus suggests the provenance of this material from outside the island (Gasanova et al. 2018: 89). Pigments' geographic distribution analyses show a range of current localities of discovery for orpiment sources (Figure 5.9).[295] The closest sources to Cyprus are Greece, Turkey, and the Middle East.

In antiquity, the presence is attested in Egypt.[296] Outside Egypt, Roger Moorey (1994: 328) proposes other geographical provenances: Julamerk in Kurdistan, Goramis in Iran, Syria, and Anatolia. Particularly, to support this hypothesis, the Assyriologist underlines the presence of orpiment in the cargo of the Uluburun shipwreck (on the southern Anatolian coast), dated to the late 14th century B.C.[297], and today assumed to be set sail from a Syro-Palestinian port. According to the studies on the Uluburun shipwreck[298], the

[295] The database of the Hudson Institute of Mineralogy collects information on minerals and the localities of provenance or where they are found (www.mindat.org). (https://www.mindat.org/min-3021.html)

[296] Orpiment traces are present in Egyptian painting (Colinart & Delange 1996: 37-38; Lee & Quirke 2000: 113-115). Remains of orpiment in pure form have been found on the Eighteenth and Nineteenth-Dynasty sarcophagi of kings and the Thutmose IV tomb's walls. In general, the date of the earliest use of orpiment is not easy to trace, but it should be surely earlier than the Eighteenth Dynasty (New Kingdom). Some traces of pigment use are identified during the late Old Kingdom (Lee & Quirke 2000: 115). Lee & Quirke (2000: 115) also cite the existence of earlier studies (Barthoux 1926: 251-267) that propose the area of Kharga Oasis and St. John's Island in the Red Sea as possible local provenance of this material.

[297] According to the latest dendrochronological and radio-carbon dating the shipwreck is dated around 1330-1300 B.C.

[298] For studies on the Uluburun shipwreck, see Bass 1986; Bass 1987; Bass et al. 1989.

presence of the cargo of Cypriot pottery and Cypriot copper ingots well fits the possible provenance of material from the East and the connection with Cyprus as an intermediate port where to exchange material and for continuing the route towards mainland Greece. It is a route that might have persisted through time and possibly during the Archaic period.

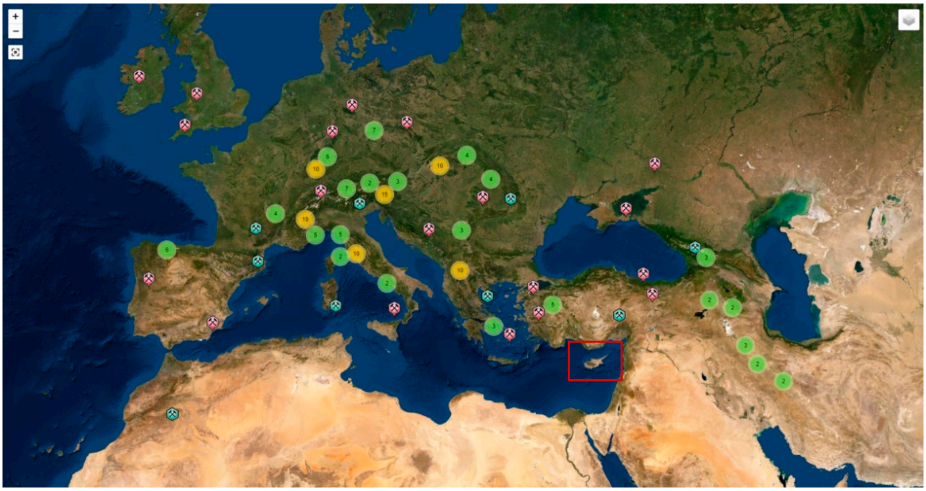

Figure 5.9
Geographical distributions and localities for orpiment (www.mindat.org).

Beyond the specific provenance of the orpiment identified on the A.I.816 figurine, an interesting example tends to convey, from an iconographic perspective, the importance of this pigment for religious ritual representations. In the well-known panel of Pitsa, Greece (Figure 5.10), dated to the 6th century B.C., the use of orpiment in a religious scene[299] has been found to depict decorative bands, belts of the *peploi*, and other elements present in the scene (Brecoulaki et al. 2017).[300] The panel represents a ritual ceremony with strict bonds with the statuettes dedicated and found in the

[299] Other panels from Pitsa show arsenic elements (orpiment): the panel fragment 16465 on a chiton's decoration and the panel 16467 (ritual dance) on some female figures' hair. The remains identified on the fragment panels 16466, initially identified as orpiment, have been recognised as realgar (Brecoulaki et al. 2019).

[300] Its presence seems to be the earliest occurrence of these kinds of pigments in ancient Greek paintings and polichromy.

Ayia Irini sanctuary and their setting, which wants to represent a scene from life.[301]

Orpiment was used to imitate shiny surfaces or some elements of the attire (e.g., decoration of the *peploi*). It can be supposed that some people participating in the religious procession, like musicians and offerors, were provided with rich and decorated clothes. Some Ayia Irini statuettes (e.g., the A.I.816 flute player) may have represented the importance of these characters in the ceremony and their prominent position within the sanctuary.

The yellow orpiment, with its availability outside Cyprus and rarity with respect to the most common use of iron oxide yellow pigments, makes supposing of more expensive costs, and therefore possibly connected to a more elevated social status, or higher economic availability, of the worshipper who dedicated the statuette to the sanctuary's divinity.

The rarity of orpiment on the Ayia Irini figurines, beyond the fact that few analyses have been carried out on their pigments, might be due to its disappearance. Arsenic pigments (orpiment and realgar) are extraordinarily light-sensitive and fade or disappear quickly (Leach &Tait 2000: 227-253). The small, faded orpiment traces found on the sampled figurine confirm this theory. Moreover, the cleaning treatment with acid substances carried out by the SCE after the discovery may have worsened the situation and eliminated many decorating pigments.

[301] As underlined by Fourrier (2007: 124) regarding the territorial sanctuary in Cyprus, it must be assumed that there were regular processions, like the one that led, on a more recent date, the pilgrims of Nea Paphos, new urban centre, to the sanctuary of Aphrodite in Kouklia (*Strabon*, XIV, 6.3 C683). It is a hypothesis that might be proved by the discovery of the SCE of an ancient road that led from Mersinaki to Soloi and from there, through the hills of Vouni, to Limnitis; possibly, a route taken by the *panegyries* which, starting from the capital city, went to the "rural" sanctuary of Limnitis (Gjerstad et al. 1937: 400-402).

Figure 5.10
Wooden votive plaque from Pitsa (Corinth, Greece), 550-525 B.C. (540-530 B.C. NAM). National Archaeological Museum of Athens, no. A 16464, also known as “Procession in honour of the Nymphs” (Photo: NAM CC BY-NC-SA 4.0).

Mullenbock and Brorsson found that a few objects in their sample, although belonging to an earlier and a later period with respect to the Archaic period's core of the statuettes, have different clay compositions. Therefore, scholars hypothesise a possible off-island origin (Mullenbock & Brorsson 2016). The sole presence of a pigment not available on the island, so far identified only on one statuette (A.I.816), cannot provide certainty on provenance. Nevertheless, such a finding can contribute to the discussion regarding foreign presence connected to the production of this or other statuettes: local or foreign artisan, foreign worshipper, imported material, or a combination of those. The A.I.816 figurine is assimilated for typology and period to the remaining production (Gjerstad attributes it to Type 5, while the current geometric analysis associates it to the group akin to Type 6). Nevertheless, some features stand out compared to the other artefacts (see further in the chapter – *auloii* players and musicians). This finding suggests that the object had higher economic value than other statuettes. Moreover, it points to possible diversified use of pigments according to the type of statuette and to the reason for its dedication.

5.4 Digital spatial re-contextualisation of the figurines' groups and their social significance

The method developed for this research has allowed investigation of the figurines according to their life cycle: the conceptual phase as a lump of clay, the production, and the dedication in the sanctuary, where they remained sealed for centuries. As mentioned in Chapter 1 (footnote 2, p. 9), a more structured study of coroplastic, including context analysis, has been established in the last decades. In earlier years, 3D digital technologies encouraged the reflexive approach (Hodder 1997, 1999, 2000, 2003, 2005) in archaeological processes because they enhanced several operations difficult to operate in a real environment.[302] So, digital technologies simplified procedures and enhanced interpretation (Berggren et al. 2015).

In the current case, the Ayia Irini sanctuary's digital reconstruction served as a reflexive method to re-evaluate the excavation process in a virtual environment. The 3D GIS, acting as a spatial digital archive, allowed the integration of various data and the creation of a virtual environment to test a reflexive re-interpretation of the excavation. I relied on archaeological reports, old plans, drawings, and sketches superimposed on the modern landscape to reconstruct layers, structures and positions. It is an integrated, holistic three-dimensional access point used to re-assemble, visualise and re-evaluate the excavation process. The sanctuary reconstruction and the artefacts' re-contextualisation in the 3D space are used to analyse patterns (relative chronological deposition and horizontal and vertical spatial distribution) among the sampled figurines' positions within the assemblage. Furthermore, this analysis served to understand the productive chain of the figurines, as reflected by the 3D digital and analytical investigations, and the function and social role of the context through the analysis of their spatial distribution.

Many archaeological sites excavated in the past were not sufficiently documented due to limitations in the methodologies, undeveloped technologies, and human errors. The 3D GIS analysis of the Ayia Irini sanctuary raised several issues: inconsistencies within the maps, errors, and lack of measurements. Indeed, the digital analysis uncovered inaccuracies in the original documentation, suggesting that the SCE archaeologists produced some of the records at the end of the excavation, leading to contradictory

[302] These operations include relations among objects, events, re-assessment, and discontinuous information integration.

post-interpretations. As highlighted by Houby-Nielsen and Fourrier, the digital analysis confirms inconsistencies in the stratigraphy and sheds light on the position of objects.

Calculations based on the distribution of the sampled artefacts do not confirm Gjerstad's stratigraphy. Instead, they tend to demonstrate the presence of two main archaeological stratifications separated by a more natural interval. This geological episode may be identified with a flood[303] followed by another natural event that caused the site's abandonment.

The spatial re-position of the figurines within the virtual sanctuary visualised the sub-groups, as obtained by the previous analyses, and drew up some chronological and social conclusions on their production and deposition.

The observation of the spatial distribution of the statuettes automatically attributed to the <u>conical helmet</u> sub-group shows their spread presence on both sides of the altar, suggesting a longer production and deposition. The items on the south-east side (e.g., A.I.130, A.I.110, and A.I.217) seem to be placed later since they are close to the altar. Similarly, the south-west group were placed later; in some cases, we can trace a sequence (A.I.341, A.I.332 and A.I.328).[304] The remaining figurines (A.I.760 and A.I.741), also positioned on the south-west side, suggest successive placements with respect to the previously cited ones to start a new area of deposition beginning from the back and moving towards the front. Together with the other statuettes (compatible with the SCE Type 5), they prove a long and massive production, and possibly confirm, as already suggested by Fourrier, a production from a nearby area strictly connected to the sanctuary (e.g., Soloi).

The 3D shape analysis automatically created another sub-group (under the main group compatible with SCE Type 5), constituted of quite a few figurines characterised by a <u>truncated hat</u>. The 3D visualisation and non-invasive chemical investigation identified the similarities and demonstrated a possible shared production environment. The observation of their spatial distribution pattern tends to confirm the previous analyses. Five statuettes, a majority, are concentrated on the south-west of the altar. Some of them (A.I.321 and A.I.349) are placed in the same area, very close, and positioned

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303 It is worth to underline that this geological episode is the only one that SCE describes as composed of 'alluvial sand',

304 The succession of the inventory numbers assigned to these statuettes shows that the excavation in this area proceeded starting from the altar area and in succession from the front towards the back.

on the same height level (L11, 94.4), further confirming the presence of a common hand in the production of these two objects. The position of this group seems quite advanced and closer to the altar with respect to the remaining mass of the artefacts and might suggest a chronologically more recent production and deposition. The data at disposal show a possible chronological deposition sequence that might see a contemporaneous deposit of A.I.321 (maybe A.I.405) and A.I.349, almost in front of the altar. The figurines A.I.710, A.I.740 and A.I.1868 seem to be the last in terms of deposition, the first two occupying the south-west side of the altar and the third one the south-east side, both more rarefied in terms of artefacts deposition. Such an arrangement suggests that as the space filled, cult followers continued to place their votives along the outer wings of the sanctuary.

Traces of possible organic black have been found on A.I.321 and A.I.405. The figurines are placed on the same side of the altar and close to each other. The spatial distribution confirms earlier assumptions: the figurines were created by the same hand/workshop, possibly during the same baking batch. Depending on the baking technique, the objects may have suffered oxide reduction or charring.

The digital distribution analysis of the sub-group of figurines with short triangular heads (A.I.1304, A.I.1342, A.I.1572, A.I.220, A.I.223, A.I.236, A.I.289, and A.I.552) seems to shows the production by a similar hand and deposition in different periods. From the positions' analysis, it can be assumed that some statuettes were created and placed earlier than others (e.g., A.I.1342, A.I.552). The remaining ones (A.I.220, A.I.223, A.I.236, A.I.289, A.I.304) might have been created during the same period since they are at the same level, quite advanced towards the altar and all positioned on the same imaginary horizontal line. A.I.1572 may be the last creation because it is placed on what would appear to be the sterile layer behind the large statues. It is as though worshippers started to fill any available space.

The observation of the spatial distribution of the smaller handmade sub-groups constituted of figurines with long-truncated hat and turbans provided only partial new information. The spatial distribution of the long-truncated hat figurines shows their proximity (e.g., A.I.1547 and A.I.1548). It supports their similarity and possible production by the same hand in the same time frame, as possibly confirmed by the deposition in the sanctuary side by side and in the same row. On the contrary, the distribution shows no indicative relationships for the group of figurines with turbans. The small number in these groups might not be sufficient for interpretation.[305]

The current study identified inconsistencies in the qualitative classifications of earlier scholars. For example, the inconsistency in attributions of some figurines to one group instead of another (Type 6/Type 5, imports from Idalion/Soloi A-1) appears to be a constant in previous studies. The automatic geometric analysis addressed inconsistencies thanks to identifying clear elements production techniques and led to a more meaningful grouping (akin to the SCE Type 6). The shape similarity clusters a number of figurines in the sanctuary in a high deposition level, ca. 100.5 (A.I.28, A.I.195, A.I.60; A.I.37, A.I.981, A.I.984, A.I.895, A.I.834 and A.I.816). This combination of information suggests a production within the same workshop and chronologically later respect to the other main handmade group (the one akin to the SCE Type 5).

The analytical investigation of the Ayia Irini artefacts identified the presence of local provenance pigments, except for one figurine (A.I.816), where traces of orpiment, not locally available, are detected. The attribution of this figurine to this group, instead of the other as proposed by previous classification traditions, the high similarity with the others, its high stratigraphic position, and the presence of different materials confirm the novel classification. These elements, coupled with the small number of items in the assemblage, hint at a possible later production date, suggesting, as already proposed by Fourrier, that they were made in another area that was subject to foreign influences and not strictly connected to the sanctuary (e.g., Idalion?).

The spatial distribution of the handmade statuettes seems to confirm the presence of two main groups, better defined by the shape analysis, akin to the Type 5/Soloi and the Type 6/Idalion with two different temporal productions. Furthermore, for the most consistent group, the variability and spatial distribution of the subgroups tend to demonstrate the presence of several operating hands, of which, at the moment, it is not possible to determine the exact number and a long production time-span that only further analyses will solve. Instead, the second group is characterised by greater uniformity attributable to a common production environment, and the arrangement points to a later period, both with respect to the other handmade group and the wheel-made figurines.

[305] The small number of artefacts might also cause the inaccuracy in the automatic clustering happened with the shape analysis.

The geometric analysis subdivided the wheel-made/moulded figurines into three separate sub-groups. The spatial distribution of the artefacts demonstrates that the figurines created with the "long hair" *mould y*, at least some of them, might have been deposited, and therefore also produced, earlier than the ones created with the "long hair" *mould x*. Specifically, the position at the same height level (94.1) on the same horizontal line, and the presence of a very similar decoration for some figurines (A.I.1496 and A.I.1499), suggest a contemporary deposition and production. Instead, the other figurines (e.g., A.I.1507, A.I.888, A.I.1250) seem to have been placed a short time after. Secondary elements suggest a common production.

The spatial distribution of the figurines attributed to the "long hair" *mould x* (A.I.83, A.I.85, A.I.88, and A.I.113) seems to demonstrate a slightly more recent, or partly contemporaneous, deposition with the figurines attributed to the *mould y*. The *mould x* figurines appear positioned pretty close to each other and put forward nearer the altar on its south-west side, not covered by others, responding to a later chronological *criterium* and maybe also to specific choices (e.g., available space). The close deposition tends to confirm the automatic geometric clustering and suggest a contemporary production.

Finally, the spatial analysis shows that the short hair mould figurines, which constitute the largest wheel-made subgroup, were placed on the south-east side of the altar(a few items, A.I.584, A.I.713 and A.I.1128, on the outer south-west side; others, A.I.1205, A.I.1235, A.I.1249, A.I.445 and A.I.1485, on the centre south). Their position, close to the altar, possibly suggests a more recent production with respect to the remaining wheel-made figurines created with the other moulds (*mould x* and *mould y)*.

Interestingly, some figurines (A.I.1205, A.I.1235, and A.I.445), positioned very close to each other, present all the same secondary elements (e.g., arms) that might suggest a common hand in the production. Moreover, they share the same elements with those attributed to the "long hair" *mould x* (figurine A.I.1535 is also attributed to *mould y*). Since we assumed that the "long hair" *mould x* figurines were produced and deposited earlier, this element might suggest that "short hair" figurines were produced slightly before the rest of the group by the same hand. A similar pattern is observed in other figurines belonging to the "short hair" mould (e.g., A.I.883, A.I.872, A.I.876, A.I.877 and A.I.881), also positioned close to each other and presenting the same secondary elements which, once again, may suggest contemporary production by the same hand.

Therefore, in this larger group of the wheel made/moulded figurines, some differences and similarities are visible, which may suggest a possible collaborative production environment, maybe attributable, at least to a couple of individuals (maybe three?) as already assumed following the geometric analysis.

It is striking that there are more handmade figurines since moulds and wheels are easy and fast techniques, and their knowledge is spread throughout the island during the studied period. This fact, already argued by Ikosi (1992-93: 275), favours Fourrier's suggestion that these were produced away from Ayia Irini (2007). The smaller number might justify a production outside the area strictly connected to the sanctuary represented by handmade figurines (e.g., Soloi) and confirm possible imports, or individual(s), from other areas of the island.

The spatial analysis of all the figurines' clusters determined by the previous geometric and analytical classifications shows that, within the same groups, some statuettes' positions suggest a contemporary deposition and production and, in some cases, by the same hand. The spatial distribution observation suggests that the deposition took place on horizontal lines (or semi-circular), sometimes inclined in different directions, to define rows in succession from the back towards the front, suggesting an organisation that responds to chronological and spatial criteria but is also connected to other reasons.

The differences in height levels are partly dictated by the orography of the terrain or by chronological deposition (for instance, positioned beside, one after the other, or covering others). In this regard, the presence of semi-circular structures proposed by Houby-Nielsen as platforms for the deposition cannot be confirmed or rejected since few figurines belonging to the current sample are placed in the corresponding area (so far, those present are all the same height level and suggest a regular base). The observation of the distribution patterns, as Jaimee Uhlenbrock underlines, often creates more questions than answers (Uhlenbrock 2016: 1). This intricacy is also evident for the Ayia Irini statuettes distribution patterns, as also highlighted by Houby-Nielsen regarding the stratigraphy and placement of the votives. Indeed, beyond the chronological criterion, this research demonstrates that the figurines' deposition certainly responds to choices due to space requirements, social reason connected to the worshipper, or, in some cases, to rituals. For instance, the figurines created with the wheel and those belonging to the "short hair" mould suggest deliberate positioning – central and close to the altar. Here, we find the most extensive collection of figurines with animals, offerings, and musical instruments, figures more directly connected with the rituals.

The "short hair" figurines with animal offers are mainly deposited on the front line of the assemblage, towards the outer part. Particularly, the figurines seem to bear small sheep. Recent research on the faunal assemblage from Ayia

Irini analysed the remains of bones found inside and outside the temenos and identified the animal species present at the sanctuary: Bos Taurus, Ovicaprids, Cervidae, and Equus Caballus (Colosimo 2015). These results confirm the presence of some animals represented by the assemblage, similar to the votive plaque from Pitsa, suggesting the will to represent a real scene.

We can attribute the same intention to other statuettes. A.I.880 holds a vase and stands in front of the altar, close to the interpreted cult object (the stone A.I.938). Gjerstad et al. (1935) do not specify the type of vase in their description, but the shape, with no handles, can be attributed to a specific ceremonial vase offering, a stemmed cup or a rhyton (Figure 5.11). The figurine represents, therefore, a ritual activity, such as drinking or pouring libations, specific actions that might usually occur at the sanctuary during rituals involving the presence of offerings, food/drink, and, of course, music, like, once again, the religious ceremony in the votive plaque from Pitsa shows.

Figure 5.11
Figurine A.I.880 holding a stemmed cup/ rhyton related to a ritual offering (Vassallo©).

Cypro-Archaic sanctuaries have attracted the interest of many scholars since their discoveries. As Anastasia Leriou underlined, the researchers focussed on specific themes while leaving others behind (Leriou 2017: 525). For instance, some scholarships concentrated on the analysis of the votives (e.g., stylistic, technological, and chronological study of the terracotta figurines and statues), others on the architectural structures, and others on the identification of the divinities worshipped or on the social and political identity of the sites also in connection with their topography (Gjerstad et al. 1935; Gjerstad 1948; Karageorghis 2002; Fourrier 2007; Ulbrich 2008; Papantoniou 2012; Papantoniou 2013; Iacovou 2013b). Research on Cypro-Archaic rituals mainly relied on the iconography aspect and almost neglected the contextual analysis's role in reconstructing and interpreting the rituals (Malone et al. 2007: 2-3).[306]

This research included clay figurines with musical instruments and their context. Rituals investigation is not the main aim of this study. However, the 3D digital re-contextualisation allowed access to the sampled figurines, dispersed in different museums in a unique space, clearly visualising them together and highlighting useful information to the archaeological interpretation. The iconography and specific depiction of the figurines representing musicians, their function and ritual context, the reason for that kind of representation and position, the choice of an instrument instead of another, and the meaning in the ritual view provide hints to understanding the sanctuary social significance (Bellia & Marconi 2016: 10).

Usually, terracotta figurines found in Cyprus represent lyre, aulos, tympanon, and cymbal players, most of them offered as a votive gift and associated with priests, worshippers, dancers, and animals, as it happens in the Ayia Irini assemblage (Karageorghis 1995: 37; Vendries 2013). The majority of the musicians in this research sample fall into the “short hair” group, and few items in the handmade one, respectively:

- Six (6) *tympanon* players;
- Two (2) *aulos* players.

Aulos players. The figurines A.I.816 and A.I.834 represent *aulos* players. In both cases, the instruments are lost but are suggested by the advanced hand position and other elements. The two auletes are positioned more or less centrally between the two tympanon-player groups, suggesting a connecting and prominent position. The *auloi* were, in fact, probably the most common

[306] This lack should not be attributed entirely to scholars but, unlike other chronological periods, to the non-existence of written sources or gaps in the past excavations’ documentation for the material and period under study (Reyes 1994; Osborne 2004; Leriou 2015; Leriou 2017). Thus, it does not allow testing hypotheses that have to be based only on the information that can be extracted from technical analysis, comparisons, and logic deductions.

musical instruments[307] and were used in different ceremonies and rituals such as processions (προσοδίων) and sacrifices, particularly in sanctuaries to stress all different moments of the ceremony (Gasparri 2014; Nordquist 1992; Nordquist 1996; Braun 2002).[308]

The *aulos* was composed of a cylindrical or conical tube (*bòmbyx*). Within the tube, further cylindrical pieces could be inserted to increase the length of the instrument. Through a narrowing (*hyphòlmion*), other connecting pieces with ovoid shape (*hòlmoi*) and the same function could also be inserted. On top of these elements, the mouthpiece was inserted. The reed was inserted in the narrow connecting part between them and the *hòlmos* (*zeugos*)[309] (Sutkowska 2009; Sasch 1980: 157; Wilson 1999: 70). The instrument's main characteristic is the presence of two pipes[310] that can be played simultaneously with single or double reeds[311]. Their structure became even more complicated, with further holes, rotatory ring mechanisms[312], and

[307] The connection between the aulos and the Greek cult is crucial that Herodotus highlights its lack of its use in the Persian cult (1:132).

[308] Papadopoulou provides a variety of information on the *auloi*: on the typology of the areophones (Papadopoulou 2004: 347), on the literary sources (Papadopoulou 2004: 349-350), on the *auloi* as ex-votos (Papadopoulou 2004: 351-352) and the *auloi* found in sanctuaries (354). Regarding this last topic, epigraphic sources and archaeological remains testify that offering the musical instruments to gods had the aim to prepare them to the worshippers' requests favourably. Moreover, the use of instruments was giving more holiness to the rituals, contributing to creating an atmosphere of "spiritual relaxation" and "spiritual refinement" (Gasparri 2014).

[309] The reed (simple or double) is a changeable piece of the aerophone instruments: its vibrations allow the production of the sound. According to archaeological finds and literary sources, the material used for reeds was the cane/reed. The most and still used for constructing musical instruments in the Mediterranean regions is the *Arundo Donax* (Majnero & Stanco 2009). For instance, Theophrastus in the IV-III century BC (*Περί Φυτών Ιστορίας,* 4, 11, 4-5), provides information about the process of the cane for the production of the reeds.

[310] Many Greek paintings, confirmed by few archaeological finds (e.g., the auloi of Pydna and the Elgin aulos), show instruments with two pipes of the same or different lengths (Psaroudakes 2008).

[311] Double-tube reed aerophone instruments had a long tradition: the first representations are from the Near East and the Cycladic culture. The Near East example is a cup relief from Adab dated circa 2800 BC and conserved at the Oriental Institute Museum of the University of Chicago (Orthmann 1985). The Cycladic example is an idol from Keros, dated to the end of the 3rd millennium BC and conserved at the National Archaeological Museum of Athens (van Schaik 1998).

[312] There are no explicit representations in the Greek depictions of the sixth to fifth centuries BC. The only example that could be interpreted as the rotary rings is the drawing on the

sliding rods[313] used to lengthen the *harmonia* (Hagel 2004, 2008, 2009, 2012; Psaroudakes 2008).

The mouthpiece was probably stabilised by the presence of the *phorbeia* (Figure 5.12), usually a leather band that covered the mouth, and it was tightened behind the nape (Comotti 1988; Comotti 1991).[314] Today its function is still under discussion, and various interpretations exist (Bélis 1986: 205-218).[315] It is reasonable to think that it was used to facilitate the so-called "circular breathing" (Wilson 1999, 70-72) or keep the reeds and the instrument steady during the melody's execution. The resistance to playing a reed instrument causes extended cheeks of the performer, connected to circular breathing, requiring much effort in breath issuance and lung power for the player. The *aulos* player inhaled the air through the nose, keeping sound continuity through the closed mouth, acting as a reservoir (Csapo 2004: 207-248). Using that technique, the player does not show fatigue in breathing and performs long continuous music without pause (Dolazza 2016).[316]

Nevertheless, the *aulos* players are also represented without *phorbeia*. This lack could be explained with simple and short exhibitions, as testified by symposia scenes where the auletes are instead depicted without it.[317]

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votive plaque from Pitsa (550-525 BC). It seems that this interpretation could bring the dating of such a device one century earlier respect to what is reported in the literary source.

313 The movable nature of that part could be suggested by the rings shown in the Attic Polion painter's crater (5th century BC), conserved at the Metropolitan Museum of Art in New York. This element can also be seen in the *aulos* from Pydna (Psaroudakes 2008) and Copenhagen (Psaroudakes 2002).

314 Pollux mentions the term in the *Onomasticon* (*Poll. 4.70*) as a part of the *aulos*.

315 An update regarding the *querelle* on the function of the *phorbeia* comes from the personal communication with Emiliano Li Castro, a scholar in archaeomusicology and one of the leaders of the European project, "EMAP - European Music Archaeology Project" (http://www.emaproject.eu/).

316 Plutarch (Ἠθικά Ethika. Περὶ ἀοργησίας, VI, 32, 456b-c), telling about the myth of Athena, says that the *phorbeia* was used for hiding the deformed swollen cheeks while playing. Although many scholars accepted this interpretation, it may be connected to the myth and not acceptable. It is, in fact, possible to keep the cheeks close to teeth without the presence of such an element (see Dolazza 2016 for further references)

317 Maybe, the use of that element became necessary with the introduction of the auletic competitions.

Figure 5.12
Red figures kylix painted by Epiktetos, from Vulci, 510 BC. British Museum, no. E38 (Photo: British Museum CC BY-NC-SA 4.0).

Although the two aulos players of the sample cannot provide further information on the instrument due to its lack, they can instead support knowledge of the ritual thanks to other elements, such as the *phorbeia*. In the case of A.I.834, this is not visible. Also, the SCE description is ambiguous in the interpretation ("Band around head falling down on back of head probably indicating hair" – Gjerstad et al. 1935: 697). Nevertheless, computer graphics filters identified on the 3D digital replica the presence of an element covering the mouth with lines going towards the ears and highlighted the rendering of the swollen cheeks, showing the music playing and the ritual in action (Figure 5.13a).

Concerning the A.I.816 figurine, something peculiar has been identified: a detail different from the *phorbeia* iconography of the other figurine and, in general, from other known representations (e.g., paintings, coroplastic productions) can be noticed. In the SCE description, it is possible to read: "Statuette with cylindrical, solid body; splayed base; both hands holding a flute; square head; thick bands around head; mouth-band tied behind the head to hold flute in place; knap-sack hanging in a strap on left shoulder […]". In reality, the stripe is not tied behind the head as usual, but it consists of the same band going around the head, creating a unique piece used as *phorbeia* and headgear (Figure 5.13b). It can be postulated that the connection might represent the small red elements (probably the different colour underlines the presence of different materials) depicted both in the votive plaque from Pitsa and in the Epiktetos' kylix (Figure 5.10 and Figure 5.12).[318] However, in both examples, there is no visible trace of connection with a headgear. Moreover, in other figurines, the turbans are rendered differently. Alternatively, with the discovery of not-local pigment (orpiment) on the figurine, this element might suggest a different kind of *phorbeia*, perhaps even connected to a different geographical provenance.

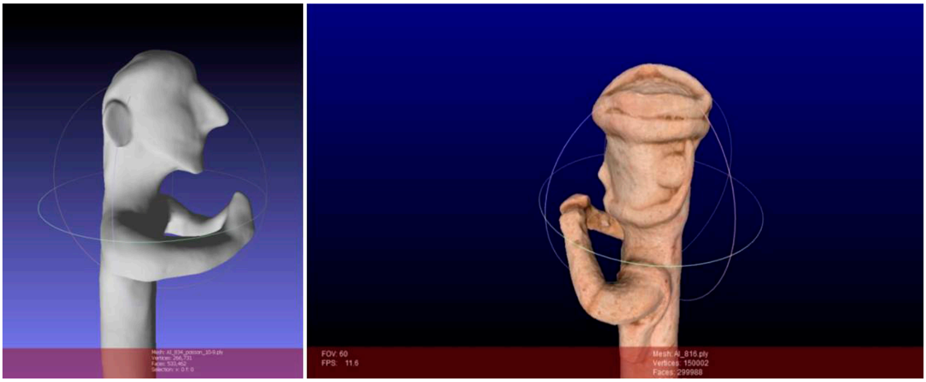

Figure 5.13
a) Aulos player conserved at the Medelhavsmuseet (A.I.834); b) aulos player conserved at the Cyprus Museum (A.I.816) (Vassallo©).

The wooden votive plaque depiction from Pitsa and the Attic cup of the Epiktetus painter from Vulci (Figure 5.10 and Figure 5.12) represent the musicians standing in a row to imitate motion. This element suggests that the auletes played and walked during the ceremonies, possibly for a long time.

Therefore, using the *phorbeia* was necessary to guarantee the instrument's stability and allow the *aulos* player to focus only on the breath and hand position (Dolazza 2016).

A further clue that the A.I.816 figurine might represent an *auloi* player in motion during long ceremonial performances is given by the presence of the knap-sack he wears on his left shoulder, where to possibly insert the previously mentioned sliding rods that could be added and eliminated as

[318] In these two depictions, the flute players wear a band encircling the mouth and linked to an element passing on top of the head.

needed. The knap-sack seems to describe something real and suggests that the musician was usually moving and needed his material during the itinerant performance. Moreover, this element connects with mobility and the different geographical provenance previously mentioned. Like in the Hellenic μουσική, objects, music, and music players probably travelled, creating a shared cultural space.

Most likely, in the current Ayia Irini sample, the two *auloi* players represent male characters: in the A.I.834 figurine, the beard is rendered through an accentuated chin; in the A.I.816 figurine, there are no specific characterising elements, but that did not make the archaeologists doubting the identification with a male character. Literary sources and depictions show that men and women could play the *aulos*.[319] In this case, the possible dedication to a male warfare god might justify male *aulos* players' presence. According to Daniela Castaldo, this difference is not associated with specific male or female rituals (Castaldo 2010). However, the presence of only male *auloi* players in the Ayia Irini assemblage might support, instead, the hypothesis that the gender of the *auloi* players could have been associated with the type of divinity venerated in the sanctuary.[320]

Tympanon players. The other figurines of this research sample connected with the music and the ritual are six tympanon players (A.I.245, A.I.1867, A.I.92, A.I.101, A.I.102, and A.I.109). These "short hair" moulded figurines stand on the assemblage's south-east wing. They are in an advanced position and seem to represent, together with the figurines bearing offers, a procession within the sanctuary similar to the one depicted in the votive panel from Pitsa. The desire to represent a realistic scene and the embodiment of the worshippers in the performance is also observable in the realistic rendering of these musicians: for instance, taking as examples some of the Ayia Irini figurines, Karageorghis, in his study of the small Cypro-Archaic small figurines, highlights their hands' position. The instrument is held on the chest with the left hand, moved towards the left and beaten with the right hand. These statuettes show the tympanon's exact position and how to play it during the ritual (Karageorghis 1995: 40). The geometric analyses confirm a high level of expressivity, realistic representation, and expertise.

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319 Herodotus tells how Aliatte, king of the Lydians, marched the army to the sound of both male and female *syringes* and *auloi* (Herodotus., Ἱστορίαι I, 17).

320 Another case might support the hypothesis, although chronologically posterior (V-IV century B.C.) and geographically far, the sanctuary dedicated to Demeter Malophoros in Selinunte (Μεγάλη Ἑλλάς – Magna Graecia), where the *aulos* is associated with female characters (Gasparri 2014).

Differently from the *auloi* players, the *SCE* archaeologists identified the Ayia Irini tympanon players as female characters because of their hairstyles. Nevertheless, they also report no other elements that can be characterised as feminine and inform about the presence of attached or painted beards.[321] This characteristic is interesting because it connects the gender issue with the archaeological interpretation of the music and the ritual representation, the production, and the provenance of the specific material: in a few words, the social significance of the sanctuary in its multivariate aspects.[322]

Karageorghis, in his study of the coroplastic art of Ancient Cyprus, treats the matter of tympanon players' gender (Karageorghis 1995: 40, 42). The figurines described are supposed to be male in case of no clear evidence (e.g., breast, specific female facial features). Nevertheless, he admits to using arbitrary criteria and reports that other researchers refer to them as female figures without explanations (Ohnefalsch-Richter 1893: 397) or doubts about it (Schürmann 1984: 35; Bisi 1966). Moreover, using several examples, Karageorghis highlights that female tympanon players are more common than male ones (Karageorghis 1995: 40; Braun 2002: 118-133).[323]

Nobody specifically addressed the sexual attribution and gender representation of the Ayia Irini tympanon players and the other "short hair" moulded statuettes.

Fourrier proposes that the Ayia Irini moulded-head figurines may be Kitian, then over-moulded or stylistically derived from there but produced in Lapithos. A production in Lapithos can be plausible, and an element could be added to this hypothesis.

A gender division distinguishes the religious practices in the Archaic phase of the Cypriot sanctuaries, showing a dedication (and a production?) of male or female figurines and statuary (Ulbrich 2008; Ulbrich 2012; Ikosi 1993: 13;

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321 According to Andres Reyes, the representation on a seal from Ayia Irini (Archaic period?) might be possible proof of tympanon players' attribution to female characters: the scene represents a male seated lyre player during a ritual banquet and turning towards a female tambourine player (Reyes 1994). That is a widespread ritual banquet scene in the Ancient Near East and often related to musicians (Dentzer 1982; Scardina 2009).

322 Beyond the Ayia Irini material, scholarships on other Cyprus and Mediterranean case studies already demonstrated the connexion between figurines and rituals/music. This link is pretty sure considering the places where the terracotta figurines were found: tombs, graves, and votive deposits connected to temples and sanctuaries (Garcia-Ventura & López-Bertran 2013: 118, 134).

323 The examples are figurines from the Late Bronze Age, the female tambourine players on Cypro-Phoenician metal bowls representing religious rituals or ritual banquets, specimens in limestone sculptures, and reliefs and carvings from the Near East, where the representation's influence might come from.

Houby-Nielsen 2009). Depending on this interpretation, Ayia Irini terracottas, representing male figures, were linked to a male divinity cult (Ikosi 1991-1992: 268).[324]

In Lapithos, the presence of a female sanctuary, therefore characterised by material representing female figurines, is attested (Ikosi 1992-93: 269, map. 1). The Ayia Irini statuettes could be related to that production. The statuettes could have been originally produced (or re-moulded) in the Lapithos area by a skilled coroplast (given the high quality of these figurines) and dedicated in Ayia Irini after readjusting the model to a male sanctuary by adding the beard.

It is already well-known the habit in ancient productions of creating a 'new object' by adding elements, such as the addition of painted beards or moustaches to change the type from female to male (Higgins 1967: 31; Biers 1989: 10; Biers 1994: 512). Similarly, the moulded-head artefacts included in the current sample prove the same process: the will to create something different from the standard used, a female head, and transform it into a male one when needed by changing the decoration or adding a feature to the already produced head. This detail may explain why beards were added with pigment and clay pieces. The co-presence of both strongly underlines the choice of representing male characters.

Facial hair, pointed chins, and beards are typically linked to males and masculinity (Lopez-Bertran & Garcia-Ventura 2016: 209-210). Certainly, the possibility of representing a hybrid and more ambiguous character beyond the gender binary classification that somehow limits a possible more comprehensive array of gender identities and that might be connected to possible performative roles (Knapp 2009: 141-142; Garcia-Ventura & Lopez-Bertran 2013: 129-130), cannot be excluded entirely. Although the main scope of the statuettes was to draw attention to their social role and ritual, represented by specific gestures and attributes, their social function was gendered and, therefore, the ritual and the gender of the performers were too important not to be casual (Zeman-Wiśniewska 2012: 155).

[324] In the assemblage, there are also a couple of figures understood as female, but, as in other cases, the criteria used here to attribute a gender to those statuettes are not always reliable. For instance, Sandra Christou, instead of female, proposes a dual-sexed representation (Christou 2009).

5.5 Artisan(s)-hand or workshop attribution: a standardised analysis

Experimental tests involving several contemporary artisans who re-produced ancient statuettes proved that when many statuettes share common elements, there is a greater likelihood of a common hand (Alexandrou 2016: 128 *et seq*.). Furthermore, fewer common elements (or the presence of one or two different elements) can be referable to small variations created by the same artisan or related to production in a similar environment (e.g., a workshop).

Such proof relies on the semantic, standardised analysis concluding the methodology developed for this research. The last step consists of comparing all the data through a semantic partonomic description used for cross-checking in a semi-automatic way the validity of the results obtained with the previous analyses.

After the results of the digital and analytical investigations, the cross-check tested the similarities that we might relate to the production by the same hand or to different individuals operating within the same workshop.

Semantic analysis highlights common features and provides an overview of the production. Thanks to the features' retrieval and the analysis of the resulting combinations, it has been possible to identify the similarities among figurines and assess the clusters created by geometric or analytical descriptors.

For instance, by filtering the data through the feature 'truncated hat', the resulting statuettes (A.I. 238, A.I. 283, A.I. 321, A.I. 349, A.I. 405, A.I. 710, A.I. 740, and A.I. 1868) present other features such as "black pigment", "red pigment", and "yellow pigment". In some cases, there is the co-presence of only two features, pointing to the attribution of retrieved figurines to the same group. In other cases, there is the co-presence of all four features, highly indicating not only the specific production choices of a workshop but the deliberate choices of an individual in the representation of specific figurines.

Other feature associations retrieved by the semantic filtering tested the goodness of the automatic geometric analysis. For instance, the association of the features 'medium pointed hat – painted beard/face – lozenges decoration' clusters suggests the attribution of the statuettes to the same artisan environment (Type 6/Idalion imports). The analysis allows us to attribute the statuettes not precisely attributed by previous scholars (e.g., A.I. 195, A.I. 60) to the same group with greater certainty. The combination of the features further confirms the automatic clustering based on shape analysis.

Similarly, within the wheel-made and moulded objects, it was possible to highlight patterns related to the rendering of the arms that we could not quantitatively classify. The filtering option based on the ‘arms’ retrieves the feature ’tipped hands’ on some of the wheel-made statuettes, which appears to be present within all three mould groups. The presence of this element is very often associated with the clay-attached beard (painted or not) on short hair heads, which instead is completely absent on long hair heads. Only a few ‘short hair’ moulded heads present a different rendering of the arms, and most with just the painted beard. Such a combination, easily summarised by the filtered and retrieved fields, suggests that at least a couple of individuals (maybe three?) collaborated on these statuettes and possibly with a division of work visible in the recurrent features throughout the entire wheel-made group.

This semi-automatic retrieval system for sorting and clustering based on semantics supports identifying functional patterns to confirm the production of the statuettes by the same individuals or workshop. In the future, a database built on a structured ontological description (CIDOC CRM and its extensions) and the partonomy already developed within this research (see 3.4.2 and 3.4.1) will guarantee the automatization of the retrieval/comparison system, and it will provide a tool for validating the robustness in the definition of a Type through the association of its different characteristics.

6.Conclusions

The hypothesis of this doctoral thesis started: “Can a comprehensive approach, based on quantitative criteria identified and defined by applying 3D digital and analytical methods, enhance the stylistic and typo-technological interpretation in coroplastic studies?” I addressed this question by investigating the relations between geometry, material, context, and semantics. I have proposed a new way of studying coroplastic production, specifically the small figurines of Ayia Irini, to understand its social significance. To do so, I considered characteristic features of the artefacts: shape, size, texture, surface, and appearance. Although these attributes form the basis of any coroplastic investigations, archaeologists describe and study them using qualitative and subjective methods, undervaluing quantitative ones.

As a solution, I proposed a quantitative and multidisciplinary method using a 3D digital and analytical chaîne opératoire. This method supports more accurate archaeological classification by reducing subjectivity in the criteria selection. The automatic and semi-automatic identification of similarity characteristics helps create new categories and gives novel interpretations of the production and provenance of materials.

I applied the implemented approach to a sample of small terracotta figurines from Ayia Irini, Cyprus, to evaluate the potential and effectiveness of the proposed method and to solve issues identified in past studies. My case study raised archaeological sub-questions, for which I collected new evidence and insights leading to a new classification and interpretation.

The application of quantitative analysis highlighted specific characteristics that helped to delineate the categories created in the past and infer further insights about their stylistic and typo-technological production. On the base of the sample used for this research, the quantitative analysis tends to demonstrate the presence of two big groups of small terracottas, the handmade and the wheel-made, classified thanks to the semi-automatic identification of the part of the figurines best suited to run the selection and to give testimony on the difference (the lower body). The analysis also tends to assess levels of accuracy of the artefacts using production techniques and to sub-group them according to possible levels of expertise of the artisans. The 3D digital analysis of the figurines also tends to prove the presence of production patterns such as specific clay's rendering, crafting traces, and standardisation. The digital analysis features clear quantitative criteria for classifying and evaluating objects to identify group or individual work. The study demonstrates the presence of standardisation for wheel-made figurines and set ratios for handmade figurines, pointing at preliminary sub-classifications for common hands.

The automatic shape analysis run on the figurines' heads tends to show the presence of two main groups, the moulded and the handmade, confirming the central subdivision of the material into two groups according to their production technique.

The automatic analysis identifies three different moulds in the sample: one for the "short hair" and two for the "long hair" heads. Specifically, the digital analysis suggests, for the moulded head group, the presence of at least two hands operating in a shared artisan environment, possibly even a collaborative work involving a sort of differentiation in the preparation of the parts, for example, the presence of novices engaging in piece work.

The automatic comparison of the handmade heads, in general, tends to confirm the validity of Gjerstad's "reference-figurines" approach, which may point to the same hands in the productive chain. First, it confirms the presence of two macro groups, compatible with Gjerstad's Type 5 and 6, but with clear definitions and attributions. This division supports Fourrier's assertion of two workshops operating at different times and in different areas. Furthermore, within the largest group, we can attribute smaller sub-groups to the presence of different hands, at least four individuals, as also confirmed by the integrated analytical and spatial analysis.

I applied analytical non-destructive methods to extract physico-chemical properties from a subset of artefacts of the Ayia Irini assemblage. The main aim was to identify the chemical characterisation of the materials (e.g., pigments) to identify elements that prove the production provenance or the attribution to the same workshop or individual and further support the classification and interpretation of the artefacts under study.

The results of the application of physico-chemical analyses show the use of local raw material (iron mineral pigments) that fits the hypothesis of previous scholars about local production and local imports (e.g. Soloi, Kition/Lapithos). Nevertheless, the discovery of orpiment, an imported material, indicates a provenance outside the island, either being the pigment, the artefact, the artisan or the worshipper, or from an area of the island subject to foreign influences. We can assume the provenance of the material from the East, which fits the island's exchange system with the area in the studied period and Houby-Nielsen's speculation on the Levantine characters of Ayia Irini's finds. The use of rare and expensive pigment implies its use for religious representations and to signify the social status and wealth of the worshipper.

The results of the physico-chemical analyses for the attribution to specific hand groups tend to confirm the results obtained through shape analysis and to mark the association of some figurines to the production of the same hands.

A future chemical analysis programme for other figurines from the assemblage could help explore the matter of the attribution and possible imports and find if other artefacts present the same or other imported features. This information could link these objects to resources, provenance, trade networks, and social exchange.

Consequently, the groups were spatially re-contextualized in the digitally reconstructed sanctuary to explain the connection with their chaîne opératoire, both in terms of material production (e.g., common hand/workshop identification, materials), chronological relations (production and deposition) and social significance.

The digital spatial reconstruction of the sanctuary and the re-assessment of the excavation uncovered inaccuracies and inconsistencies in the original documentation, which explains the misunderstandings of the site's post-interpretation.

In this vein, this current study tends not to confirm Gjerstad stratigraphy, as formerly argued by Houby-Nielsen and Fourrier, and proves the presence of two main archaeological stratifications separated by a more natural/geological interval, that we identify with a flood, finally covered by another natural event (another flood?) that caused the abandon of the site.

Observing the spatial distribution of the figurines tends to highlight relative chronological relations that confirm the classification operated with the geometric analysis, analytical investigation, and identification of common hands in the productive chain.

The repositioning of the limited sample of figurines shows a first and long-lasting distribution of the biggest handmade figurines group (akin to the SCE Type 5), identifiable with the production of a workshop, possibly from a nearby area directly connected to the sanctuary. A smaller wheel-made group (akin to the SCE Type 7) accompanies the large handmade group. For the wheel-made group, we can construct an internal, relative chronological depositional sequence ("long hair" mould y, "long hair" mould x, and short hair mould). We might connect this group to a workshop from a nearby area not directly associated with the sanctuary. Finally, we can assume the placement of a smaller group of figurines (akin to the SCE Type 6) is attributable to another workshop, operating chronologically later and in a different area of the island.

On the base of the current sample, we cannot confirm or reject entirely the presence of semi-circular structures proposed by Houby-Nielsen as platforms for the deposition. The analysis of the distribution, although, supports her explanation for the placement of the votives. Indeed, beyond the chronological criterion, this research confirms that the figurines' deposition also responds to social and ritual choices.

The re-contextualisation of the finds' clusters obtained from the geometric and analytical investigations and their spatial analysis highlights patterns useful for interpreting the function and social role within the sanctuary. This visualisation reveals social practices we can connect with specific groups of people and roles, including artisans and worshippers, genders, and rituals.

Including all the specimens in the digital environment will shed further light on spatial relationships and the micro-stratigraphy of the small human idols. The spatial re-contextualization digitally re-unifies the collection for a holistic visualisation of the archaeological discovery. In the future, the digital system can become the instrument for the "virtual repatriation" of the assemblage, a space for experimentation and exploration of theories, methods, and discussions, including colonial research, collection dispersion, and heritage at risk.

The archaeological questions addressed in the case study and those applicable to coroplastic production were positively answered thanks to the approach developed and proposed in this study. The method demonstrated its effectiveness as a supporting tool to solve archaeological issues such as stylistic and typo-technological classification and interpretation and to provide a quantitative, transparent, and replicable basis for classification, analysis and interpretation of coroplastic material. The study focussed on a sample, but it proved to be a good pilot for the application of the methodology to the whole assemblage of the site taken into consideration, as well as expandable to other Cypriot assemblages and integrated by further automatic methods (e.g., 3D pattern recognition, machine learning), to understand the relations among other archaeological sites and to have a larger and brighter view, since based on measurable elements, about the coroplastic production of the island. Working on an extensive assemblage of artefacts is not easy, and, in such a case, sampling is a challenging activity. As this research assesses, we can decide on specific sampling strategies a priori. Still, we can employ and adapt them according to the needs and the new research questions that might arise, ensuring, on the one hand, flexibility and resilience and, on the other hand, a good sampling and valid results. Thanks to the results obtained so far by applying the developed methodology, it will be possible to proceed to a more holistic coroplastic quantitative analysis in the future.

The research on coroplastic might still be incomplete. Nevertheless, I hope the new directions of this thesis, its development of a comprehensive, multidisciplinary and quantitative approach, and its successful results encourage new practices in coroplastic research, an important field that is too often overlooked.

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Addendum

The Cyprus Museum

The Cyprus Museum covers with its material the island history from the Neolithic period up to the Early Christian times, from completed and ongoing excavations. The museum was born in 1882: the first finds housed in some rooms of the Government Offices. In 1889, the collections moved to a house on Victoria Street in Nicosia. The situation was temporal and not appropriate for the conservation of the material. In 1908, the Cyprus Museum was built, and a curator was appointed to arrange the collections in the new premises. Finally, in 1935, the British administration re-organised the museum with the enforcement of the Antiquities Law and the foundation of the Department of Antiquities that started to regulate excavations and exportation of antiquities (Pilides 2016: 3-4). Before that, due to the 19^{th} century legislation, it was possible to obtain permission to excavate and export finds. For this reason, many objects are now in different museums (e.g., the British Museum in London, the Louvre Museum in Paris, and the Medelhavsmuseet in Stockholm).

As a consequence, the Department of Antiquities started several projects to manage and preserve the material.[325] A database for the digitisation of the museum inventories was created to preserve information and unify artefacts from the same archaeological sites, divided in different museums. CADiP (Cyprus Archaeological Digitisation Programme) is the programme that aims to retrieve and manage information relating to Ancient Monuments and movable antiquities in order to protect the Cypriot Cultural Heritage.[326] The structure relies on a GIS, and all the data are linked to a metadata database that describes and gives information about monuments and artefacts (Kydonakis et al. 2012: 141-151; Pilides 2016: 5-6). In that context, the Ayia

[325] Already in the past, this was the subject of the SIMA Corpus of Antiquities (Pilides 2012: 7-24).

[326] The programme was developed under Cyprus's co-financing and the Norwegian Financial Mechanism (http://www.mcw.gov.cy/mcw/da/da.nsf/All/1A7BF21DA2D1652DC225750C00228456?OpenDocument) to create a fully digitised corpus of the movable antiquities of Cyprus. The digital database is open to the personnel of the Department of Antiquities, but in the future, parts will be open to authorised scholars for study and parts to the public for consultation.

Irini finds conserved at the Cyprus Museum have been digitally catalogued and included in the database.[327]

The Medelhavsmuseet

The majority of the Cypriot collections have been housed at the Medelhavsmuseet since 1954, year of the museum's foundation (Karageorghis 2009: 10; Styrenius 1994: 7-17; Styrenius 2012: 113-118). Before that period, the material coming from Cyprus was conserved at the Royale Castle. In 2009, the Museum received a significant donation from the A.G. Leventis Foundation and created a new Cypriot gallery. The renovation included the construction of huge blocks used as exhibition cases. The structures represent an interesting architectural work that, especially for the Ayia Irini site, allows the visitor to imagine the collection in its whole through a mirror. Nevertheless, it limits the easy access to the material for research aims (fig. 1).[328] Fragmentary material is also conserved at the Medelhavsmuseet premises: numerous finds are conserved in the "Tumba" museum storerooms, outside Stockholm. Some Ayia Irini finds conserved at the Medelhavsmuseet had additional vicissitudes. After the Cypriot finds arrived in Sweden in 1931, some artefacts were brought to various Universities where the SCE archaeologists worked. Other finds were bought by museums.[329] A document published in the digital archive of the Uppsala University museum (Gustavianum) declares that to a decision of the Cyprus Expedition Committee on 15 May 1934, some of the material had to be transferred to Malmö Museum, Uppsala University and Lund University (fig. 2).[330] A group of artefacts was conserved during the period 1961-1996 at the Röhsska museet of Göteborg and then reunified with the Medelhavsmuseet

327 Thanks to that, and with the Department of Antiquities' permission, it has been possible to access the digital database to choose a sample to be three-dimensionally documented.

328 Marie-Louise Winbladh, former curator of the Cypriot collections in Stockholm, criticises the reason for the architectural concept, explained as something to help the visitors "to feel the essence of Cyprus and experience the importance of religion in everyday life in ancient Cyprus". In her opinion, the construction gives an opposite feeling instead, contrasting the idea of the Cypriot open-air sanctuaries (Winbladh 2010: 1).

329 Einar Gjerstad, Uppsala University alumnus, after the excavation in Cyprus became director of the Swedish Institute in Rome and then professor of Classical Archaeology at Lund University. Alfred Westholm became director of the Gothenburg Art Gallery; Erik Sjoqvist was a professor of Classical Archaeology at Princeton University, and John Lindros worked for the Swedish Institute in Rome.

330 http://www.alvin-portal.org/alvin/attachment/document/alvin-record:112869/ATTACHMENT-0001.pdf

group (e.g., A.I. 1128, A.I. 1535 and A.I. 1871) (Nys & Åström 2005: 36-37); the same happened for some items in a long term deposit at Umeå University until October 2007 (e.g., A.I. 724), when they were included again in the group at the Medelhavsmuseet. Another group was brought, and it is still conserved at the Lund University Historical Museum; a few small figurines were acquired by the Malmö Konstmuseum, where they still are, and finally, some artefacts are conserved at the Gustavianum.

All the material conserved at the Medelhavsmuseet and in its stores is digitally accessible via "Carlotta", a database system developed for different museums and their collections.[331]

The Lund University Historical Museum

Lund University Historical Museum (LHUM) hosts several finds from the Stone, Bronze and Iron Ages, as well as medieval art from Scania and Classical Antiquity artefacts. Dated back to 1805, this is one of the first archaeological museums in Europe. The former Museum of Classical Antiquities (Antikmuseet), merged into the current one, was administered by the Institute of Classical Archaeology.[332] Its primary purpose was as teaching support to the educational activities of the Lund University Department of Classical Archaeology and Ancient History, established in 1909 by prof. Martin P. Nilsson, its first professor. In 1912, the Nilsson private collection was formally entrusted to the University and enlarged with other groups of material. Before 1931, the Cypriot material conserved at the museum consisted only of small vases on loan from the Nationalmuseet in Stockholm. In 1934, the museum received material from the SCE, consisting mainly of complete tomb groups and pottery from other tombs. Later, in 1957-1960, the Cypriot collection grew in pottery after some donations. Several terracotta objects and sculptures, including some from the SCE, are hosted at the

[331] http://collections.smvk.se/carlotta-mhm/web. The system is owned by the National Museums of World Culture and includes the Ethnographic Museum, Museum of World Cultures, the East Asian Museum and the Medelhavsmuseet. Other museums that use "Carlotta" are Gothenburg City Museum, Helsingborg museums, Kulturen in Lund, Malmö museums, Vänern Museum in Lidköping, Norrbotten Museum Ájtte and Rörstrands museums. The basic idea of Carlotta is to provide a flexible system, Java-based, that can be used and adapted to all kinds of museum collections. A starting point has been the CIDOC international ontology, adapted to Swedish standard SWETERM, for documenting museum objects (Rengman 2006; Larsson 1993). The accessibility to the digital catalogue allowed the choice of a group of items for their 3D digitisation and subsequent geometric analysis.

[332] The Archaeological Institute of Lund University and the Historical Museum were divided physically during the '90s. At the beginning of 2000 were also separated administratively, but the cooperation between the two institutions is always close.

museum. The permanent establishment of the museum is related to Prof. Einar Gjerstad, successor of M.P. Nilsson as a chair of the institution for many years (Åström et al. 1980: 6-7; Nys & Åström 2005 12, 46). Concerning the material from Ayia Irini, a small group of items is conserved at the premises of the LUHM, both exhibited in the museum and conserved in the storerooms placed at Gastelyckan, Lund.

Malmö Konstmuseum

The Malmö Konstmuseum houses various materials coming from different Cypriot locations. Specifically, they are eighty-three pieces consisting of bowls, plates, jugs, and terracottas. Forty-four pieces were donated in 1932 to the museum by Dr. Hugo Granvik, a Swedish local zoologist. The remaining thirty-nine Cypriot objects were bought in 1934 by the Malmö Konstmuseum from the SCE for 2000 kronas (fig. 2). Among them, a group of objects comes from Ayia Irini. Specifically, the inventory numbers between 25.250 to 25.257b represent terracotta artefacts from the Cypriot sanctuary. They correspond to the figurines published by the SCE with the inventory numbers A.I. 870, A.I. 884, A.I. 1033, A.I. 1929, A.I. 1962 (Gjerstad et al. 1935: 698-699, 705, 746-747), plus two other male figures heads corresponding to the inventory numbers A.I. 936 and A.I. 1842 (Gjerstad et al. 1935: 702, pl. CCIX,6, 743, pl. CXCIV,5; Karageorghis 1993: 14, no. 22, pl. V: 4 and 22, no. 50, pl. XIII:4; Nys & Åström 2005: 6, 46). Only three of the figurines conserved at the Konstmuseum represent the “small, human idols’’: A.I. 870, A.I. 1929 and A.I. 1962.

Gustavianum, Uppsala University

The Gustavianum, the Uppsala University museum, conserves various archaeological objects: among them, there is a number of Ayia Irini artefacts (Nordquist 1978; 11-36). Many are currently on display in the museum rooms.[333] Most of them are published in ‘Alvin’, the digital catalogue of the institution.[334]

[333] https://www.gustavianum.uu.se/

[334] https://www.alvin-portal.org. Alvin’ is a platform for archiving and publishing digital resources both for digitised physical Cultural Heritage objects and born-digital data. The platform uses specific descriptive metadata based on MODS and EAD, developed respectively for libraries and archives by the Library of Congress (https://wiki.epc.ub.uu.se/display/alvininfo/Formathandbok)

Glossary

Artefact: it is any object made, modified, or used by humans. Usually, the term refers to a portable item.

Accuracy: accuracy of measurement is represented by the closeness of the agreement between a measured value and the true value (JCGM 2008, JCGM 2012, Li 2011).

Alignment: see **Registration**.

Authority list: (semantics) it is a list of controlled names and concepts, similarly to a vocabulary, that should be used when inserting data in a database system. The authority lists are also known as terminologies and taxonomies. These authorities can be of two types: instances of real entities (e.g., places) or conceptual descriptions (e.g., subject, material, object type). In cataloguing systems can be used a combination of thesauri. These lists often present additional descriptive information, called scope notes. The records of the list have a unique identifier (through a system number) or unique term (through an URI).

Bounding box: it is the smallest box that can contain the object.

Characterisation: in materials science, it refers to the broad and general process by which a material's structure and properties are probed and measured.

CIDOC CRM: it is an ISO standard (ISO 21127:2014) which provides an extensive ontology for concepts and information in Cultural Heritage and museums documentation. It provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in Cultural Heritage documentation.

Class: see **Type**.

Classification: with classification is meant any set of formal categories used to cluster a specific group of data. It is a group of categories (classes or types) that can be distinguished by the others according to different attributes, and that include all the entities within a specific group of study.

Compactness: in 2D, compactness is defined as the degree to which a given shape differs from a region bounded by a circle. For this reason, compactness in 2D is also defined as Circularity. This measure can be also extended to 3D and in this case the resulting shape is not a circle but a sphere.

Convex hull: it is the minimal convex polygon covering of an object.

Cultural Heritage Artefact Partonomy (CHAP): A Simple Knowledge Organisation System (SKOS) vocabulary based on an archaeological corpus of texts (archaeological publications, catalogues and excavation reports) as well as the knowledge of Archaeologists. Currently, it defines body parts and attire, decorations, and colour.

Data Model: a conceptual model of how data items relate to one another normally associated with the design of a database.

Digital Elevation Model (DEM): is a 3D computer graphics representation of elevation data to represent terrain. DEMs are used often in geographic information systems, and are the most common basis for digitally produced relief maps. The term Digital Terrain Model (DTM) is also used to define a DEM.

Eigenvectors: Eigenvectors are a special set of vectors associated with a linear system of equations, i.e., a matrix equation (Marcus & Minc 1988:144).

Euclidean distance: the Euclidean distance is the most commonly used distance metric. It is defined as the length of straight line segment joining two points.

Geographical Information System (GIS): a geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.

Geometry: it the spatial extension of an artefact. When not used in apposition, geometry is virtually synonymous with 'shape' as geometrical appearance (Biasotti et al. 2016b: 6).

Infrastructure: the physical platforms upon which systems, facilities and networks are run. It enables connectivity and provides services via applications (Hartley 2002: 117).

Interoperability: identify the necessity of data exchange between different platforms or databases, without modifying or losing that data. The creation and use of structured and standardised formats support the interoperable exchange.

Iterative Closest Point (ICP): it is an algorithm employed to minimize the difference between two clouds of points. In the Iterative Closest Point, one point cloud (vertex cloud), the reference, or target, is kept fixed, while the other one, the source, is transformed to best match the reference. The algorithm iteratively revises the transformation (combination of translation and rotation) needed to minimize an error metric, usually a distance from the source to the reference point cloud, such as the sum of squared differences between the coordinates of the matched pairs. ICP is one of the widely used algorithms in aligning three dimensional models given an initial guess of the rigid body transformation required

Level of detail (LOD): in computer graphics, the level of detail (LOD) refers to the complexity of a 3D model representation. LOD can be decreased as the model moves away from the viewer or according to other metrics such as object importance, viewpoint-relative speed or position.

Linked data: it is a semantic description(s) referenceable via a publically HTTP resolvable URI (Biasotti et al. 2016b:8).

Metadata: namely, it means data about data. It is a set of data that describes and gives information about other data.

Mean Curvature: in mathematics, the mean curvature H of a surface S is an extrinsic measure of curvature that comes from differential geometry and that locally describes the curvature of an embedded surface in some ambient space such as Euclidean space. Therefore, it highlights the overall convex or concave nature of the surface of a shape.

Mesh: is a 3D object representation consisting of a collection of vertices and polygons. The 3D object representation can be a polygon mesh, which consists of a collection of vertices and polygons that define the shape of an object in 3D (Furht 2006).

Minimal Bounding Box (MBB): it is a shape descriptor corresponding to the minimum area that bounds a given shape.

Moseley's law: discovered by the English physicist Henry Moseley in 1913 is an empirical law concerning the characteristic x-rays that are emitted by atoms.

Natural Language Processing (NLP): process that allows computer technology to "understand" human language. It can be used to convert written text into a form that can be used within a standardised environment.

Ontology: a set of concepts and categories in a subject area or domain that shows their properties and the relations between them.

Outliers: an outlier has a value that is much greater than, or much less than, other data in the set. An outlier may significantly affect the mean of a data set.

Noise: a 3D shape may be affected by different types of geometrical noise, such as topological and colour noise. The acquired data deviates from the real surface, due to several reasons, such as a lack of 3D scanner resolution. (Norton et al. 2016: 14).

PLY (Polygon File Format): it is a digital format principally designed to store three-dimensional data from 3D scanners.

Point cloud: a point cloud is a set of data points in space. The points may represent a 3D shape or object. Each point position has its set of Cartesian coordinates (x, y, and z). Point clouds are generally produced by 3D scanners or by photogrammetry software, which measure many points on the external surfaces of objects around them.

Precision: precision can be defined by the agreement between measured quantity values obtained from repeated measurements on the same or similar objects under specified conditions (therefore, described as repeatability and reproducibility) (JCGM 2008, JCGM 2012, Li 2011).

Range scan (or **range map**): during the survey, a laser scanner digitally acquires single point clouds (range scans). The integration of all the range scans creates the 3D model, given their elaboration within specific software.

Relationship: property associated with a conceptual item with a literal or concept value, e.g. <artifact> <has_Owner> <person> (Biasotti et al. 2016b:7).

Registration (point-based registration): see also **Alignment**. In computer vision, point-based registration, also known as point-cloud registration or scan matching, is the process of finding a spatial transformation that aligns two point clouds. The purpose of finding such a transformation includes merging multiple data sets into a globally consistent model. Given a pair of partially overlapping scans of an object the goal is to recover the relative transformation between the parts (Biasotti et al. 2016b:7).

Repository: in computing, a repository is the place where data are gathered, usually from multiple sources, and stored together with the related metadata.

Resolution (data resolution): meshes and point clouds are the most common 3D shape representations and can be represented with different levels of resolutions. Generally, a shape with a low resolution can be more easily managed in terms of computational efficiency, but it may have several missing geometrical details. On the contrary, a high resolution 3D shape captures very accurate geometrical details but it is difficult to manage it at computational level.

Resource Description Framework (RDF): this is a standard model for data interchange on the Web. It facilitates data merging even if the underlying schemas differ, and it specifically supports the evolution of schemas over time without requiring all the data consumers to be changed.

Semantics: the meaning of language (grounding of labels to explicit examples in a domain) (Biasotti et al. 2016b:7).

Semantic description: description of the semantics of a conceptual item typically encoded as a graph (e.g., a RDF graph). Semantic descriptions usually encompass the set of attributes and relationships that, once taken together can semantically ground a conceptual item in the context of other conceptual items (Biasotti et al. 2016b: 7).

Semantic web: a common framework that allows data to be shared and reused across application, enterprise, and community boundaries (Biasotti et al. 2016b: 8).

Shape: the physical property of an artefact, including geometry, and its visual attributes (e.g., colorimetric properties). Shape is a property of both a set of objects and a particular method of observation, or analysis (Biasotti et al. 2014b; Biasotti et al. 2016b: 6).

Shape analysis: a set of theories, methods and algorithms that concur to the formalisation and computation of properties useful to characterise the shape appearance of objects (Biasotti et al. 2014b; Biasotti et al. 2016b:6).

Shape descriptor: a concise and informative “signature” that is used to describe an aspect of a shape. These signatures are machine-understandable indexes to the informative content of 3D models.

Shape description: a concise representation that contains enough information to identify a shape as a member of a class (Biasotti et al. 2016b:6).

Shape Diameter Function (SDF): provides a stable approximation of the diameter of a 3D object with respect to a view cone which is centred to the surface. From this, a single scalar value of "Prevalent Thickness" is extracted.

Shape Index: it highlights the concave nature of an object surface.

Shape retrieval: refers to the task of finding the (3D) models in a database that best match a given query model (Tangelder & Veltkamp 2004; Tangelder & Veltkamp 2008; Biasotti et al. 2016b: 6).

Shrinkage: is the degree of reduction or downsizing (S). It is as well expressed as a percentage. Shrinkage can be affected by several variables, such as density, rate of drying, or even the size and form of the object (Moitinho de Almeida 2013: 118).

Simple Knowledge Organization System (SKOS): a W3C recommendation designed for representation of thesauri, classification schemes, taxonomies, subject-heading systems, or any other type of structured controlled vocabulary.

Thickness: a shape descriptor that is computed using the Shape Diameter Function (SDF) giving an "average" thickness for an object.

Type: a type represents one of the classes in a typology. A type consists of a group of objects that have common features and that can be distinguished by other groups. It is clear that a type is not a stable concept, being dependent by different perceptions about it, new material, and so forth.

Typology: a typology is a specific kind of classification in which the entities are assigned into equally exclusive categories (or types), defined according to the same set of criteria.

Unit: the units are entities taken as a standard of measurement.

Variable (or criteria of identity): a variable, or criteria of identity, is a characteristic that can vary from entity to entity (e.g., "colour") and it can be used for the differentiation into types. The expression of a variable is considered as an attribute, such as "blue". Therefore, "blue" is considered an attribute of the variable "colour". In archaeological classification, for "variable" we should intend a particular kind of observation on an object and with "attribute" we should identify a particular value or range of values of that variable (Cowgill 1982: 31). The selection of variables and attributes depends much on the purpose of the classification.

Vocabulary: terms used to label conceptual terms organised in a list, thesaurus or ontology. Vocabulary includes labels for conceptual items and relationships (Biasotti et al. 2016b: 7).

White balance (WB): in photography and image processing, colour balance is the global adjustment of the intensities of the colours or colours correction (typically red, green, and blue primary colours). An important goal of this adjustment is to render specific colours – particularly neutral colours – correctly. Hence, the general method is sometimes called grey balance, neutral balance, or white balance.

XML (Extensible Markup Language): the xml format is the standard format for structured document/data interchange on the Web. Like HTML, an XML document holds text annotated by tags. However, unlike HTML, XML allows an unlimited set of tags, each indicating not how something should look, but what it means. This characteristic is invaluable to information sharing.

Catalogue

In the following Tables, the statuettes sampled for the current research are described: those conserved at Lund University Historical Museum (Table 1), the Cyprus Museum (Table 2), the Medelhavsmuseet (Table 3), and Malmö Konstmuseum (Table 4). Each table consists of four columns: the ID given to the item in the current research, the inventory number (the one given by the SCE and, in some cases, the one attributed by the hosting museums) and its image. The third column reports the description provided by the SCE and, if available, by the hosting museum. The last column provides new information and comments by the thesis author: e.g., new measures taken during the study; comments related to the "reference-figurines" and Types attribution, and identification of new features. The descriptions show several differences, highlighting the lack of information and the mistakes identified between the literature sources and the present analysis.

Table 1.
Figurines sampled at LUHM.

ID	INVENTORY NO.	LITERATURE DESCRIPTION AND MUSEUM INFORMATION	NEW INFORMATION AND COMMENTS (Vassallo©)
1	A.I. 649 (573 in LUHM archive) 	"Statuette as no. 79; longer, rounded beard. Head broken at neck. Height 20.8. L11. 94.7" (Gjerstad et al. 1935: 693).	"Reference-figurine" A.I 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 649 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127).

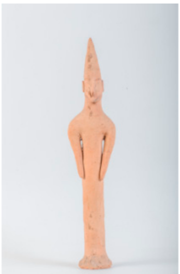
2	A.I. 771 (577 in LUHM archive) 	"Statuette as no. 137; triangular beard; long, concave helmet; shawl falling from left shoulder across breast to lower part of right arm. Height 27.2. L11. 94.7" (Gjerstad et al. 1935: 696).	"Reference-figurine" A.I 137. Since A.I. 1803, explicitly attributed to Type 5, is similar to A.I. 137, therefore A.I. 771 can be attributed to Type 5. A.I. 1803 is included by Fourrier in the stylistic sub-group named 'Soloi A.2' (Fourrier 2007: 90, 128). Nys & Åström (2005: 12) doubt about the exact inventory number of the figurine. The cross-check between the description in Gjerstad et al. (1935: 696) and the number drawn on the figurine confirms the correspondence. Drill hole under the base
3	A.I. 842 (569 in the LUHM archive) 	"Statuette as No. 79; short, straight-cut beard. Top of helmet missing; broken at middle. Red-brown clay; black core. Height 21.0. L10 94.3" (Gjerstad et al. 1935: 698).	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 842 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Both in the hand-written and in the machine typed version of the LUHM inventaria, the item is wrongly listed as A.I. 342 (cf. Törnkvist 1970: 69, 116). In the hand-written inventarium the number has been changed with the hand-written number "842". The wrong number is also reported by Nys & Åström (2005: 12).
4	A.I. 1223 (579 in LUHM archive) 	"Statuette as no. 233; trapezoid head; undigitated hands. Neck broken; lower right arm and part of band around head missing. Reddish slip. Height 26.4. L10. 94.1" (Gjerstad et al. 1935: 716).	"Reference-figurine" A.I 233. Since A.I. 1219, explicitly attributed to Type 5, is similar to A.I. 233, therefore A.I. 1223 can be attributed to Type 5. A.I. 1219 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127).

5	A.I. 1299 (574 in LUHM archive) 	"Statuette as no. 79; very short beard. Height 20.3. L10. 94.1" (Gjerstad et al. 1935: 718).	"Reference-figurine" A.I 79. Since A.I. 399, explicitly attributed to Type 5 is similar to A.I. 79, therefore A.I. 1299 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). The literature does not mention that the right arm is missing.
6	A.I. 1507 (580 in LUHM archive) 	"Statuette as no. 53. Ladder-band along sides of body; black beard. Height 18.3. K10. 94.1" (Gjerstad et al. 1935: 727).	The figurine A.I. 53 is similar to A.I. 52, therefore the "reference-figurine" is A.I. 52. Traces of colour and decoration identified: hair painted black, residues of black painted beard and eyes painted black. Black decoration of two parallel lines on the shawl and of three parallel lines on the waist; ladder-band on the right shoulder and along the sides of the body. Traces (fabric, tools or fingers) to smooth the surface
7	A.I. 1547 (570 in LUHM archive) 	"Statuette as no. 269; nearly horizontal shoulders. Neck broken; right ear missing; top of helmet chipped. Height 19.7. L9. 94.1" (Gjerstad et al. 1935: 730).	"Reference-figurine" A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 1547 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127).

8	A.I. 1548 (571 in LUHM archive) 	"Statuette as no. 269; shoulders less sloping; longer rounded beard. Height 22.4. L9. 94.1" (Gjerstad et al. 1935: 730)	"Reference-figurine" A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 1548 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Nys & Åström (2005: 12) doubt about the attribution of the figurine to A.I. 1548 (question mark). The cross-check between the description in Gjerstad et al. (1935: 730) and the number drawn on the figurine confirms the correspondence. Left ear is missing.
9	A.I. 1587 (578 in LUHM archive) 	"Statuette as No. 79; longer, triangular, rounded beard. Black border at base. Base damaged. Height 27.8. L9. 93.1" (Gjerstad et al. 1935: 732)	"Reference-figurine" A.I 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 1587 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127).
10	A.I. 1916 (576 in LUHM archive) 	"Statuette as no. 576; trapezoid head; narrow, straight-cut, long beard; right arm vertical; left arm bent holding a sword below arm-hole; arms with undigitated hands. End of sword missing. Traces of colour. Light slip. Height 17.8. M9. 94.0" (Gjerstad et al. 1935: 745).	"Reference-figurine" A.I 576. A.I. 576 is explicitly attributed to Type 5 (Gjerstad et al. 1935: CCXXXI, 9) therefore A.I. 1916 can be attributed to Type 5. A.I. 1916 (and A.I. 576) is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Right arm is missing. Turban rendered through a double clay coil.

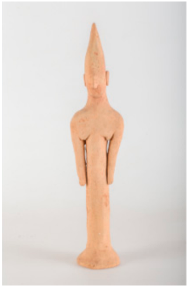
Table 2.
Small figurines sampled at the Cyprus Museum.

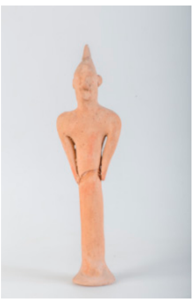
ID	INVENTORY NO.	LITERATURE DESCRIPTION AND MUSEUM INFORMATION	NEW INFORMATION AND COMMENTS (Vassallo©)
11	A.I. 28 	“Statuette with body as no. 42; rectangular head; pellet mouth, wig-shaped hair. Helmet, eyelids, ears, moustache, beard, and hair are painted black, shawl covered by black network, two black lines across waist. Left arm missing; broken at waist. Brown-clay; light slip. Height 21.0. L9 100.2” (Gjerstad et al. 1935: 676).	“Reference-figurine” A.I. 42. Since A.I. 42, is explicitly attributed to Type 6 (Gjerstad et al. 1935: CCXXXI, 11), also A.I. 28 can be attributed to Type 6. A.I. 42 is included by Fourrier in the stylistic sub-group of the ‘Imports from Idalion’ (Fourrier 2007: 91, 131). Weight: 213 gr (presence of a modern base) Presence of black pigment traces, more or less faded, creating geometric decoration (group of lines, lozenges).
12	A.I. 37 	“Statuette body as no. 42; rectangular head; short, straight-cut beard, band round head; statuette dressed in a straight shawl over both shoulders. Red-brown clay, light slip, partly turned red. No traces of colour. Waist broken; band around head and left ear missing. Height 21.3. L11 100.5” (Gjerstad et al. 1935: 676). 21 cm (CM catalogue)	“Reference-figurine” A.I. 42. Since A.I. 42, is explicitly attributed to Type 6 (Gjerstad et al. 1935: CCXXXI, 11), also A.I. 37 can be attributed to Type 6. A.I. 42 is included by Fourrier in the stylistic sub-group of the ‘Imports from Idalion’ (Fourrier 2007: 91, 131). Weight: 190 gr Some traces of black, more or less faded, has been detected
13	A.I. 60 Type 6 	“Statuette as no. 57. Eyes, eyebrows, beard painted black; angular lines on shawl, vertical lines along sides of body and arms. Height 23.2. L9 99.6” (Gjerstad et al. 1935: 677). 23,1 cm (CM catalogue)	“Reference-figurine” A.I. 57. A.I. 57 is also described as similar to A.I. 41 that, in turn, is similar to A.I. 42. A.I. 60 is explicitly attributed to Type 6 (Gjerstad et al. 1935: CCXXXI: 12). A.I. 42 is included by Fourrier in the stylistic sub-group of the ‘Imports from Idalion’ (Fourrier 2007: 91, 131). A.I. 60 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 323 gr Presence of black pigment traces, more or less faded, creating geometric decoration (group of lines, V pattern).

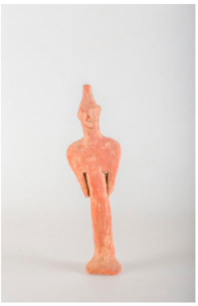
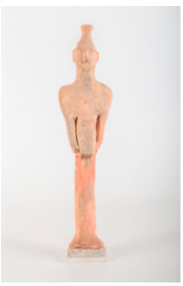
14	A.I. 82 	"Statuette as no. 80, but with triangular, rounded beard, black, encircling line round base of helmet, face, neck, and lower arms painted black; black, transverse lines at elbows. Height 25.2. L11 97.5" (Gjerstad et al. 1935: 678). 25.3 cm (CM)	"Reference-figurine" A.I. 80 Weight: 235 gr Presence of black pigment traces, more or less faded, creating geometric decoration (band)
15	A.I. 83 	"Statuette with body as no. 52; moulded, ovoid, rather triangular head, put in separately; slightly sloping forehead; curved, projecting nose; rather thin lips; rounded chin; narrow, lancet-shaped eyes with lids and eyebrows in relief; large ears provided with large earrings; hair in compact mass down back of the head and along sides; straight shawl draped over shoulders. Hair and eyes painted black; horizontal lines on shawl; vertical lines along sides of body; transverse lines at waist. Height 21.4. L11 97.5" (Gjerstad et al. 1935: 678). 21.6 cm (CM catalogue)	"Reference-figurine" A.I. 52. Weight: 266 gr. No traces of earrings as reported by SCE. Traces of black pigment, creating geometric decoration (group of lines). Hair and eyes painted black. Three horizontal parallel lines on the shawl and on the waist; two parallel vertical lines along the sides of the body.
16	A.I. 88 	"Statuette as no. 83. Height 25.4. L 11. 97.8" (Gjerstad et al. 1935: 678) 25 cm (CM catalogue)	"Reference-figurine" A.I. 83. Weight: 517 gr Possible residue of black colour on top of the head

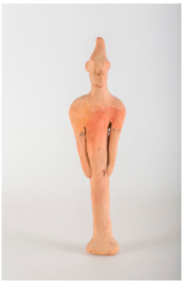
17	A.I. 96 	“Statuette as no. 86; rather long rounded beard; both arms bent over breast holding a quadruped. Hair, eyes, and beard painted black; black neck-lines; horizontal lines along shoulders; vertical lines along sides of body, horizontal line at waist; encircling band round base, eyes of quadruped painted. Light slip. Height 18.1. L9 93.6” (Gjerstad et al. 1935: 678). 19.2 cm (CM catalogue)	“Reference-figurine” A.I. 86 Weight: 207 gr Traces of black pigment that create geometric decoration (group of lines). Hair, eyes and beard painted black; two horizontal lines around the neck and three around the waist; vertical band/line on the shoulders and arms and along the body sides; black band around the base. Animal’s eyes painted black.
18	A.I. 99 	“Statuette as no. 96; bands of ladder-pattern along sides of body, and around waist. Height 20.7. L 9. 93.6” (Gjerstad et al. 1935: 678). 20.7 cm (CM catalogue)	“Reference-figurine” A.I. 96 Weight: 247 gr Traces of black pigment that create geometric decoration (group of lines, ladder pattern). Hair, eyes and beard painted black; two horizontal lines around neck; residues of black bands on the shoulders/arms; black double ladder pattern on the waist; ladder pattern along the body sides; black band around the base (a bit under the hole). Possible trace of black on the animal eye
19	A.I. 102 	“Statuette as no. 101; tympanon brown-red; black and red strokes above border of base. Height 20.2. L9. 93.6” (Gjerstad et al. 1935: 678). 20.3 cm (CM catalogue)	“Reference-figurine” A.I. 101 Weight: 257 gr Traces of black pigment that create geometric decoration (group of lines). Hair, eyes and beard painted black; band along shoulders/arms; three horizontal parallel lines on the waist (only the upper two also on the back); vertical line on both body sides; band around the base. Traces of black (and red?) on the external part of the tympanon and lines around its edge (possible traces of red in the inner side) In the digital catalogue of the CM there is a photo that doesn't correspond to A.I. 102.

20	A.I. 110 	“Statuette as no. 79. Red clay; red slip. Height 22.4. L9 93.9” (Gjerstad et al. 1935: 679). 22.1 cm (CM catalogue)	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 110 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 259 gr
21	A.I. 111 	“Statuette as no. 52; longer, rounded beard. Hair, eyes, and beard painted black; angular black and red lines from neck to waist; black lines along arms ending in two black, transverse lines at elbows. Height 20.3. L 9. 93.9” (Gjerstad et al. 1935: 679). 20 cm (CM catalogue)	“Reference-figurine” A.I. 52 Weight: 223 gr Visible traces of black and red pigments that create a geometric decoration (“V” pattern). Hair, eyes and beard painted black; “V” pattern starting from the neck to the waist with black and red alternate lines (possible presence of red points close to the neck). Residues of black vertical lines on the shoulders, cut on the arms by two small parallel lines on the middle of the arm (to indicate a tunic?); black band around the base.
22	A.I. 125 	“Statuette with solid, cylindrical body; splayed base, wide, sloping shoulders; vertical arms with undigitated hands; square head, rather trapezoid; marked eyebrow line, pellet nose and ears; long, rounded beard; conical, straight-sided helmet with straight top. Brown clay, light slip. Height 25.0. L9 93.9” (Gjerstad et al. 1935: 679). 24.9 cm (CM catalogue)	No “reference-figurine”. Weight: 335 gr The digital catalogue of the CM says "both arms are upraised", but A.I. 125 has both the hands along the body.

23	A.I. 130 	"Statuette as no. 124, but with no border round base. Height 26.5. L9 93.9" (Gjerstad et al. 1935: 679). 26.2 cm (CM catalogue)	"Reference-figurine" A.I. 124. Since A.I. 1833, explicitly attributed to Type 5, is similar to A.I. 124, therefore A.I. 130 can be attributed to Type 5. A.I. 1833 is included by Fourrier in the stylistic sub-group named 'Soloi A.2' (Fourrier 2007: 90, 128). Weight: 330 gr Very few traces of black pigment, more or less faded, have been identified
24	A.I. 142 	"Statuette as no. 138; square head, pointed beard, long, straight helmet; shawl of square outline. Broken at waist; left arm, and lower part of right arm missing. Brick-red clay, red slip. Height 25.5. L11 94.4" (Gjerstad et al. 1935: 679) 25.5 cm (CM catalogue)	"Reference-figurine" A.I. 138 Weight: 362 gr Close analysis suggests that the missing and broken parts have been reconstructed (presence of different material respect to the original.
25	A.I. 195 	"Statuette as no. 79. Broken neck and arms. Red clay, red slip. Height 22.3. L9 94.8" (Gjerstad et al. 1935: 681). 16.6 cm (CM catalogue)	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 195 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Traces of black paint are used to render the eyes, the mouth and the beard. Three black parallel lines at different height decorate the pointed hat. Traces of black faded pigment create a lozenges pattern on the front of the shawl and three parallel lines on the back. Two parallel line at waist (group of lines, lozenges pattern). Light slip. Weight: 150 gr (presence of a modern base).

26	A.I. 217 	"Statuette as no. 73; short, rounded beard. Red-brown clay; red-brown slip. Height 24.9. L9 93.6" (Gjerstad et al. 1935: 682). 23.3 cm (CM catalogue)	"Reference-figurine" A.I. 73. Weight: 328 gr
27	A.I. 233 	"Statuette with cylindrical, solid body; splayed base; oval head; very short beard; turban and three or two bands around head; vertical arms. No traces of colour. Left arm and nose missing. Slip partly turned brown-red. Height 22.8. L9 93.6" (Gjerstad et al. 1935: 682). 22.8 cm (CM catalogue)	"Reference-figurine" (A.I. 233). Since A.I. 1219, explicitly attributed to Type 5, is similar to A.I. 233, therefore also A.I. 233 can be attributed to Type 5. Nevertheless, Gjerstad attributes similarity of A.I. 233 both to a figurine in Type 5 (A.I. 1219) and a figurine in Type 6 (A.I: 811) (Gjerstad et al. 1935: CCXXXI, 2, 13) A.I. 1219 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127); while A.I. 811 is included in the stylistic sub-group named 'Soloi A-2'. Weight: 302 gr The digital catalogue of the CM says 'prominent nose' but no information that is now missing.
28	A.I. 238 	"Statuette as no. 79; rather trapezoid head; triangular, rounded beard. Broken at waist and base, parts of base missing. Height 21.6. L9 93.6" (Gjerstad et al. 1935: 682). 22 cm (CM catalogue)	"Reference-figurine" A.I. 79- Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 238 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 207 gr Few small traces of red on the right arm and black traces on the back of the head have been identified. Identified traces of red decoration on the shoulders and on the right arm (as to draw the sleeve of the tunic), plus a small yellow spot.

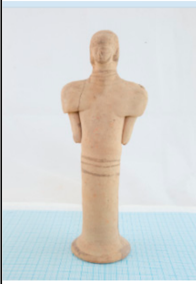
29	A.I. 245 	“Statuette as no. 92. Hair, eyes, and beard painted black; angular lines on neck; transverse lines at waist; fingers roughly painted; border at base. Black and red radiating lines encircled by black border on the tympanon. Height 19.4. L9. 93.4” (Gjerstad et al. 1935: 682-683). 19.2 cm (CM catalogue)	“Reference-figurine” A.I. 92- A.I. 92 is included by Fourrier in the stylistic sub-group derived from a ‘Kitian production (Import from Lapithos?)’ (Fourrier 2007: 91, 131). Weight: 235 gr Hair, eyes and beard painted black; two horizontal parallel black lines on the neck; two black lines creating a V pattern on the neck; two transverse parallel black lines on the waist; large black band on the frontal part of the base; two black lines on the right arm and black lines on the right hand; tympanon decorated with black and red radial pattern on both sides and black band on the edge. The decoration is only frontal.
30	A.I. 283 	“Statuette as no. 145, triangular, rounded beard, roughly indicated shawl. Traces of colour. Height 19.7. L9 93.9” (Gjerstad et al. 1935: 684). 19.4 cm (CM catalogue)	“Reference-figurine” A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 283 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 177 gr Few faded traces of black pigment. A reddish colour covers the all figurine.
31	A.I. 321 	“Statuette as no. 145. Height 24.7. L11 94.4” (Gjerstad et al. 1935: 685). 25 cm (CM catalogue)	“Reference-figurine” A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 321 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 270 gr (presence of a modern Plexiglass base) The digital catalogue of the CM says "both arms are upraised", but A.I. 321 has both the hands along the body.

32	A.I. 341 	“Statuette as no. 79. Black border on base. Height 23.5. L11 94.4” (Gjerstad et al. 1935: 685). 23.6 cm (CM catalogue)	“Reference-figurine” A.I. 79- Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 341 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 236 gr
33	A.I. 349 	“Statuette as no. 145. Height 23.5. L11 94.4” (Gjerstad et al. 1935: 686). 23.5 cm (CM catalogue)	“Reference-figurine” A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 349 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 220 gr Traces of black, yellow and red decoration.
34	A.I. 393 	“Statuette as no. 79. Nose and right arm missing, left arm broken. Brick-red clay; brown-red slip. Height 22.0. L11 94.4” (Gjerstad et al. 1935: 687). 25.7 cm (CM catalogue)	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 393 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 350 gr

35	A.I. 405 	“Statuette as no. 145; short, rounded beard. Red clay, red slip, partly darkened by soot. Height 19.5. L11 94.4” (Gjerstad et al. 1935: 687). 19.7 cm (CM catalogue)	“Reference-figurine” A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 405 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 189 gr
36	A.I. 412 	“Statuette as no. 79; long, rounded beard. Light-brown slip. Height 21.0. L11 94.42” (Gjerstad et al. 1935: 687). 20.8 cm (CM catalogue)	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 412 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 235 gr
37	A.I. 448 	“Statuette as no. 233; trapezoid head, triangular, rounded beard. Nose damaged. Height 19.6. L11 94.7” (Gjerstad et al. 1935: 688). 20 cm (CM catalogue)	“Reference-figurine” A.I. 233. Since A.I. 1219, explicitly attributed to Type 5, is similar to A.I. 233, therefore A.I. 448 can be attributed to Type 5. A.I. 1219 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 245 gr

38	A.I. 713 	"Statuette as no. 86; longer rounded beard; both arms bent over breast holding quadruped, of which forepart is missing. Left arm missing. Traces of paint. Height 20.5. L11. 94.7" (Gjerstad et al. 1935: 694). 20.5 cm (CM catalogue)	"Reference-figurine" A.I. 86 Weight 236 gr No traces of paint are visible today The description in the digital catalogue of the CM reports "both hands, bent to the chest, hold an animal". It is not mentioned that the left arm is missing.
39	A.I. 816 	"Statuette with cylindrical, solid body; splayed base; both hands holding a flute; square head; thick bands around head; mouth-band tied behind head to hold flute in place; knap-sack hanging in a strap on left shoulder. Ears and head-band are painted red; eyes, eyebrows, and the mouth-band painted black; traces of black colour on arm and body. Right arm broken; most parts of flute missing. Light slip. Height 17.8. K10. 99.6" (Gjerstad et al. 1935: 697). 18 cm (CM catalogue)	A.I. 816 is explicitly attributed to Type 5 (Gjerstad et al. 1935: CCXXXI, 10) A.I. 816 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 152 gr
40	A.I. 866 	"Statuette as no. 52, but without beard; some decoration as no. 865, but without angular lines. Height 19.4. L 10. 94.7" (Gjerstad et al. 1935: 698). 19 cm (CM catalogue)	"Reference-figurine" A.I. 52 Weight: 211 gr. Hair and eyes painted black; three lines around the neck and three around the waist; two parallel lines on both sides of the body; paint ladder-pattern on both shoulders/arms; black band on the base front. Traces of black pigment, more or less faded, creating geometric decoration (group of lines, ladder pattern).

41	A.I. 868 	“Statuette as no. 53. Black hair, eyes and beard; black neck-line from which run angular lines; ladder-band along sides of body; transverse lines at waist; lines along shoulders. Height 19.8. L 10. 94.7” (Gjerstad et al. 1935:698). 19.2 cm (CM catalogue)	“Reference-figurine” A.I. 53 Weight: 254 gr. Hair, eyes and beard painted black; two faded lines around the neck and two angular lines creating a V pattern; three black lines around the waist; ladder pattern along both sides of the body; faded lines on the shoulders. Traces of black pigment, more or less faded, creating geometric decoration (group of lines, ladder pattern).
42	A.I. 872 	“Statuette as no. 871. Both arms and lower part of body broken; part of base missing. No painted beard; only traces of colour on back of head. Height 17.0. L 10. 94.7” (Gjerstad et al. 1935: 699). 21.6 cm (CM catalogue)	“Reference-figurine” A.I. 871 Weight: 246 gr. No broken arms. Traces of black pigment, more or less faded, creating geometric decoration (group of lines, ladder pattern). Hair, eyes and beard painted black; two horizontal parallel lines around neck; ladder pattern on the shoulders (only on the shawl); three horizontal parallel black lines on waist; black line on both sides of the body; black band on the front of the base.
43	A.I. 876 	“Statuette as no. 53; triangular, painted beard; semi-circular lines below neck-line; bands of ladder-pattern along sides of body. Height 20.2. L 10. 94.7” (Gjerstad et al. 1935: 699). 20.4 cm (CM catalogue)	“Reference-figurine” A.I. 53 Weight: 233 gr The beard was added and then painted in black. Presence of broken parts at the neck and at the base then restored. Traces of black pigment, more or less faded, creating geometric decoration (group of lines, ladder pattern). Hair, eyes and beard painted black; semi-circular black faded lines (6 or 7) around neck; two faded black parallel lines at the end of the shawl; band and line around the front of the base; black ladder pattern on both sides of the body.

44	A.I. 877 	"Statuette as no. 83. Beard indicated by black colour on chin. Right arm missing. Height 21.2. L 10. 94.7" (Gjerstad et al. 1935: 699). 21.2 cm (CM catalogue)	"Reference-figurine" A.I. 83 Weight: 289 gr The right arm is broken but not missing. Part of the base was probably broken and then restored with a modern integration. Face features, beard and hair painted in black. Four (?) black parallel lines around the neck, three at waist and one band at the base front; black vertical lines along the body sides and possible black line on the shoulder/shawl. Traces of black pigment, more or less faded, creating geometric decoration have been identified (group of lines).
45	A.I. 880 Type 7 	"Statuette as no. 86; both arms bent over breast holding a vase. Hair, eyes, and beard painted black; lines along shoulders and sides of body; transverse lines at waist; black border at base; black line along rim of vase. Height 21.3. L10. 94.7" (Gjerstad et al. 1935: 699). 21.2 cm (CM catalogue)	"Reference-figurine" A.I. 86. A.I. 880 is explicitly attributed to Type 7 (Gjerstad et al. 1935: CCXXXII, 14) A.I. 880 is included by Fourrier in the stylistic sub-group derived from a 'Kitian production (Import from Lapithos?)' (Fourrier 2007: 91, 131). Weight: 248 gr. Traces of black pigment, more or less faded, creating geometric decoration (group of lines). Hair, eyes and beard painted black; band on the shoulders/arms until hands; three horizontal parallel lines at waist; band around the base front; black line on the vase (rython?) upper and lower rim. The description in the digital catalogue of the CM is different from the figurine. It says "both arms hanging down beside the body" while instead it is holding an object (a vase)
46	A.I. 881 	"Statuette as no. 53. Hair and eyes black; black neck-lines; bands of ladder-pattern along shoulders to elbows; black lines along sides of body; transverse lines at waist; black border on base. Height 22.0. L10. 94.7" (Gjerstad et al. 1935: 699). 22.2 cm (CM catalogue)	"Reference-figurine" A.I. 53 Weight: 239 gr Traces of black pigment, more or less faded, creating geometric decoration have been confirmed (group of lines, ladder pattern). Hair, and eyes painted black; two (?) lines around neck; ladder pattern on shoulder/shawl; three black horizontal parallel lines at waist; line along both body sides; band around front of the base.

47	A.I. 1249 	"Statuette as no. 105. Height 20.7. L10. 94.1" (Gjerstad et al. 1935: 717). 20.5 cm (CM catalogue)	"Reference-figurine" A.I. 105 Weight: 248 gr Traces of black pigment, more or less faded, creating geometric decoration have been identified (group of lines). Hair, and beard (maybe eyes) painted black; residues of black band on shoulders until the hands; three parallel lines at waist; ladder pattern on both body sides, faded band around front base. Traces (fingers, fabric or tool) to smooth the clay surface.
48	A.I. 1295 	"Statuette as no. 96. Height 19.2. L10. 94.1" (Gjerstad et al. 1935: 718). 19.1 cm (CM catalogue)	"Reference-figurine" A.I. 96 Weight: 246 gr Traces of black pigment, more or less faded, creating geometric decoration have been identified (group of lines). Faded traces of black hair; faded black line on shoulders/arms; traces of black on the animal; three horizontal parallel black line at waist; band around front base; black band along both body sides.
49	A.I. 1496 	"Statuette as no. 53. Black beard; lines along shoulders and along sides of body. Height 18.9. K10. 94.1" (Gjerstad et al. 1935: 727). 18.5 cm (CM catalogue)	"Reference-figurine" A.I. 53 Weight: 212 gr Traces of black pigment, more or less faded, creating geometric decoration have been confirmed (group of lines). Hair, eyes and beard painted black; one line around the neck and one v line; two parallel lines on the shoulders/shawl; two parallel lines on the shawl; three parallel lines at waist; one line around front of the base; two vertical parallel lines among body sides.

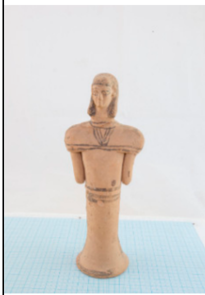
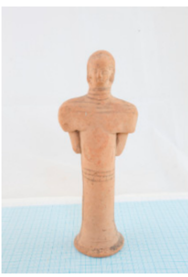
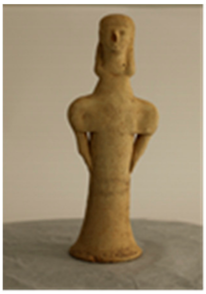
50	A.I. 1499 Type 7 	“Statuette as no. 53. Black beard; black lines round neck from which angular lines hang over breast; border lines on shawl; band of ladder-pattern along shoulders to elbows; black, vertical lines along sides of body; transverse lines at waist. Neck broken. Height 19.4. K10. 94.1” (Gjerstad et al. 1935: 727). 19.7 cm (CM catalogue)	“Reference-figurine” A.I. 53. A.I 1499 is explicitly attributed to Type 7 (Gjerstad et al. 1935: CCXXXII, 9) A.I. 1499 is included by Fourrier in the stylistic sub-group derived from a ‘Kitian production (Import from Lapithos?)’ (Fourrier 2007: 91, 131). Weight: 205 gr Traces of black pigment, creating geometric decoration have been confirmed (group of lines, ladder pattern). Hair and eyes painted black (no traces of the beard); two circular line around neck and 3 lines creating v pattern around neck; two parallel lines to limit the shawl; ladder pattern on the shoulder/shawl; three parallel black lines at waist; band along both sides of the body; band around front of the base.
51	A.I. 1867 	“Statuette as no. 92; rather long, triangular, rounded beard. Hair, eyes, and beard are painted black; encircling lines on neck; lines along arms; transverse lines at waist; black border at base; black, radiating lines and encircling border on tympanon. Height 19.3. M9. 94.0” (Gjerstad et al. 1935: 744). 19.3 cm (CM catalogue)	“Reference-figurine” A.I. 92 A.I. 92 is included by Fourrier in the stylistic sub-group derived from a ‘Kitian production (Import from Lapithos?)’ (Fourrier 2007: 91, 131). Weight: 248 gr Traces of black pigment, more or less faded, creating geometric decoration have been confirmed (group of lines, radial pattern, and band). Hair, eyes and attached beard painted black; line around the neck and line on shoulder/arms (left one is barely visible); radial black pattern on the both sides of the tympanon; two parallel black lines at waist; large black band almost around all base.
52	A.I. 1877 	“Statuette as no. 53. Black lines on neck; horizontal lines on shawl below neck; lines along shoulders to elbows; band of ladder-pattern at waist; black border at base. Height 19.8. M9. 94.0” (Gjerstad et al. 1935: 745). 19.8 cm (CM catalogue)	“Reference-figurine” A.I. 53 Weight: 257 gr (presence of soil in the body) Traces of black pigment, more or less faded, creating geometric decoration have been confirmed (group of lines, ladder pattern). Hair, eyes and beard painted black; four parallel lines around neck; band on shoulders/shawl; three parallel lines on the shawl; ladder pattern at waist and on both body sides; band around front of the base.

Table 3.
Small figurines sampled at Medelhavsmuseet

ID	INVENTORY NO.	LITERATURE DESCRIPTION AND MUSEUM INFORMATION	NEW INFORMATION AND COMMENTS (Vassallo©)
53	A.I. 0001/1250 	"Tall, hollow, cylindrical, wheel-made body; arms along sides; moulded head made separately; sloping forehead; broad, flat nose; rounded chin; large ears; hair in compact mass down the back of head and along the sides. Hard, brick clay. Buff slip. Traces of black paint on hair, beard and eyes. Black line around base, two black lines along sides of body, lines along shoulders and arms, three lines encircling waist, four angular lines below neck on the chest" Height. 18.8, Ø of base 6.2. (Carlotta catalogue).	"Reference-figurine" A.I. 52 Weight: 190 gr Hair, eyes and beard painted black; four lines creating "V" pattern around the neck; line along shoulders/arms; three parallel lines at waist; two parallel lines along body sides; band around front base.
54	A.I. 85 	"Statuette as no. 83: painted chin indicating beard; band of ladder-pattern along shoulders; black neck-line; ladder-pattern along sides of body and at waist. Height 20.7. L11 On top of no. 86" (Gjerstad et al. 1935: 678)	"Reference-figurine" A.I. 83 Weight: 250 gr Since it is described on top of A.I. 86, the height position might be 97.9(?) Possible traces of black on hair and beard (not visible); two faded lines at waist; faded band around base; big ladder pattern along body sides.
55	A.I. 92 	"Statuette as no. 52; shorter hair; both arms bent over breast holding tympanon. Hair, eyes, and chin painted black (indicating beard); black neck line; bands of ladder-pattern along sides of body and round waist; black lines along arms; encircling, black line round base. Lower part of body broken; part of base missing. Height 19.1. L9 93.6" (Gjerstad et al. 1935: 678).	"Reference-figurine" A.I. 52. A.I. 92 is explicitly attributed to Type 7 (Gjerstad et al. 1935: CCXXXII, 13) A.I. 92 is included by Fourrier in the stylistic sub-group derived from a 'Kitian production (Import from Lapithos?)' (Fourrier 2007: 91, 131). Weight: 221 gr Hair, eyes and beard painted black; two parallel lines at neck; line on both shoulders/arm until hands; ladder pattern at waist and along body sides; line around base; black line on tympanon edge.

56	A.I. 101 	“Statuette as no. 92. Hair, eyes, and chin painted black; two black neck-lines; lines along shoulders and arms; vertical lines along sides of body, three horizontal lines at waist, oblique lines on un-digitated hands, marking fingers; traces of black colour on tympanon; black border on front of base. Light slip. Height 20.9. L9 93.6” (Gjerstad et al. 1935: 678)	“Reference-figurine” A.I. 92 Weight: 275 gr Hair, eyes and beard painted black; three lines at neck; line along shoulders/arms until hands (right hand indicates fingers); three parallel lines at waist; line along both body sides; line at base; traces of black (and red?) on the tympanon.
57	A.I. 105 	“Statuette as no. 52, longer, rounded beard. Hair, eyes, and beard painted black; body decorated as no. 94. Height 20.1. L9 93.9” (Gjerstad et al. 1935: 678)	“Reference-figurine” A.I. 52 Weight N/A No traces of colours visible. Possible trace of a lost attached beard
58	A.I. 109 	“Statuette as no. 92; longer, pointed beard. Traces of black paint on hair, eyes and beard, lines along arms; arms painted black; bands of ladder-pattern along sides of body; tympanon with black border. Height 20.2. L9 93.9“ (Gjerstad et al. 1935: 679)	“Reference-figurine” A.I. 52 A.I. 109 is included by Fourrier in the stylistic sub-group of the ‘Imports from Kition’ (Fourrier 2007: 91, 131). Weight: 262 gr Hair and beard painted black (no traces visible on eye today); possible traces of ladder pattern along body sides; traces of black on hands (for fingers?).

59	A.I. 113 	“Statuette as no. 83, but without earrings; wedge-shaped lines below neck. Height 21.0. L9 93.9” (Gjerstad et al. 1935: 679) “Statuette with cylindrical, hollow, wheel-made body. Splayed base. Flattened chest. Broad, horizontal shoulders. Arms along sides. Hands shaped but undigitated. Small moulded ovoid head made and inserted separately. Back of head is flat. Modelled features include ears, eyebrows, eyes, nose and mouth. Long Egyptian-style hair or wig, ending at the joint between head and body at middle of neck gives a non-realistic long and squared impression of neck. Shawl indicated, with straight edge across upper arms. Black colour on hair, eyes and eyebrows. Three black, angular lines on breast. Black lines on shoulders. Horizontal black lines around waist. Two broad vertical black lines along each side of body. Traces of black border on base. The statuette was part of the MMs permanent Cyprus Exhibition 1989-2005 at Röhsska Konstslöjdmuseet, Gothenburg, Ikosi 1991-1992. Height: 21.2 cm (MM description).	“Reference-figurine” A.I. 83. A.I. 83 is similar to A.I. 52 and can be attributed to Type 7. Weight: 282 gr On Plan XXVIII the statuette A.I. 113 holds an animal, while the statuette with inv. no. 113 is standing with arms along body. No traces of earrings; hair and eyes painted black; three “V” lines around neck; traces of lines around waist; line along shoulders/shawl; two parallel lines along sides of body; possible line around base.
60	A.I. 220 	“Statuette as no. 73; short, rounded beard. Red-brown clay; light-brown slip. Traces of red colour on nose and ears. Height 20.8. L9 93.6” (Gjerstad et al. 1935: 682) “Statuette with solid, cylindrical body. Splayed base. Sloping, wide shoulders. Vertical arms without shaped hands. Square, rather trapezoid head. Pellet ears. Pinched nose. Short, rounded beard. Shawl over shoulders. Fainted traces of red colour on nose and ears. Red-brown clay, light-brown slip. Modern drill-hole for mounting on underside of base” (MM description).	“Reference-figurine” A.I. 73. Weight: 269 gr

61	A.I. 223 	“Statuette as no. 79. Broken at neck and left arm; top of helmet missing. Red slip. Height 22.8. L9 93.6” (Gjerstad et al. 1935: 682).	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 223 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 271 gr
62	A.I. 236 	“Statuette as no. 79; rather trapezoid head; longer, rounded beard. Black border around base. Height 18.8. L9 93.6” (Gjerstad et al. 1935: 682).	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 236 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 234 gr
63	A.I. 271 	“Statuette as no. 269, long rounded beard. Traces of black colour on body, black border on base. Left ear missing. Height 23.8. L9 93.3” (Gjerstad et al. 1935: 684) “Statuette with solid cylindrical body. Splayed base. Flattened chest. Slightly sloping shoulders. Arms along sides. Hands not shaped. Square head. Pellet ears, placed high. Pinched nose. Rounded beard. Very tall helmet. Traces of colour on back. Black border on base. Pinkish clay. Light slip. Sample taken by Gloria Ikosi 1992-03-17. Needs support. Left ear missing. Left side of head damaged. Modern drill-hole for mounting on underside of base. Start of a second drill-hole on underside of base. Exhibition; showcase 10:08:05” (MM description)	“Reference-figurine” A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 271 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 282 gr

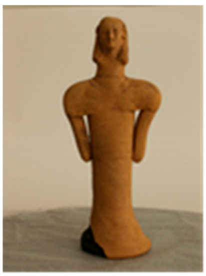
64	A.I. 289 	"Statuette as no. 73; longer, triangular beard. Traces of black and red colour on arms, red colour on body. Red-brown clay, light-brown slip. Height 21.3. L9 93.9" (Gjerstad et al. 1935: 684)	"Reference-figurine" A.I. 73. Weight: 269 gr
65	A.I. 328 	"Statuette as no. 79, longer, rounded beard. Height 22.3. L11 94.4" (Gjerstad et al. 1935: 685). "Statuette with solid, cylindrical body. Splayed base. Sloping shoulders. Vertical arms without shaped hands. Square head. Pinched nose. Pellet ears. Rounded beard. Short conical helmet. Shawl over shoulders. Brown clay, brown slip. CA I-II. Needs support. Mended at right shoulder. Traces of modern white paint on helmet. Modern drill-hole for mounting on underside of base'' (MM description)	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 328 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 259 gr
66	A.I. 332 	"Statuette as no. 79. Top of helmet damaged, head broken at neck. Brown-red clay, brown-red slip. Height 22.3. L11 94.4" (Gjerstad et al. 1935: 685).	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 332 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 247 gr

67	A.I. 340 	“Statuette as no. 73. Height 22.2. L11 94.4’’ (Gjerstad et al. 1935: 685).	“Reference-figurine” A.I. 73 Weight: 227 gr
68	A.I. 445 	“Statuette as no. 52. Traces of colour. Height 19.8. L11 94.7’’ (Gjerstad et al. 1935: 688).	“Reference-figurine” A.I. 52 Weight: 227 gr Ladder pattern along body sides and maybe line around base.
69	A.I. 470 	“Statuette as no. 124, longer, rounded beard. Reddish slip. Height 24.2. L11 94.7’’ (Gjerstad et al. 1935: 688) “Statuette with solid cylindrical body. Splayed base. Flattened chest. Sloping shoulders. Arms along sides. Hands not shaped. Square head. Pellet ears. Pinched nose. Short beard. Tall helmet. Shawl indicated. Horizontal black line on left elbow. Black border on base. Red clay. Light slip’’ (MM description)	“Reference-figurine” A.I. 124. Since A.I. 1833, explicitly attributed to Type 5, is similar to A.I. 124, therefore A.I. 470 can be attributed to Type 5. A.I. 1833 is included by Fourrier in the stylistic sub-group named ‘Soloi A.2’ (Fourrier 2007: 90, 128). Weight: 262 gr

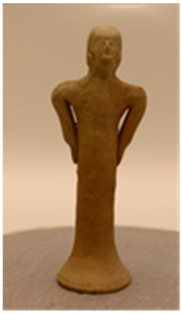
70	A.I. 552 	"Statuette as no. 73; trapezoid head, short, rounded beard: Right arm broken. Red-brown clay, light-brown slip. Height 22.8. L9 95.6'' (Gjerstad et al. 1935: 690).	"Reference-figurine" A.I. 73. Weight: 347 gr
71	A.I. 584 	"Statuette as no. 53. Black hair and eyes, two horizontal lines below neck over breast, ladder-pattern along arms to elbow; black lines from elbows to hands, two vertical lines along sides of body; three horizontal lines at waist; border on base. Height 20.8. L11 94.7'' (Gjerstad et al. 1935).	"Reference-figurine" A.I. 53 Weight N/A Black hair; two lines around neck; possible ladder pattern on shoulders/shawl; two vertical lines along body sides; line around base.
72	A.I. 608 	"Statuette as no. 269. Black border on base. Height 23.9. L11 94.7'' (Gjerstad et al. 1935: 691).	"Reference-figurine" A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 608 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight N/A
73	A.I. 710 	"Statuette as no. 145; longer, triangular, rounded beard. Black border on base. Height 22.3. L11 94.7'' (Gjerstad et al. 1935: 694).	"Reference-figurine" A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 710 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 195 gr

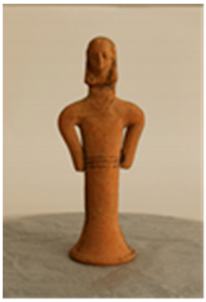
74	A.I. 723 	"Statuette as no. 269; trapezoid head; modelled eyes. Height 24.0. L11 94.7 (Gjerstad et al. 1935: 694). "Statuette with solid, cylindrical body. Slightly splayed base. Slightly sloping shoulders. Arms along sides. Hands not shaped. Trapezoid head. Pinched nose. Pellet ears. Modelled eyes. Short beard. Tall helmet. Light slip. Needs support. Mended at neck and waist'' (MM description).	"Reference-figurine" A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 723 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 272 gr
75	A.I. 740 	"Statuette as no. 739; shawl roughly indicated. Red clay; light slip, partly turned red. Right arm missing. Height 20.8. L11 94.7'' (Gjerstad et al. 1935: 695) "Statuette with solid, cylindrical body. Splayed base. Flattened breast. Sloping shoulders. Arms along sides. Hands not shaped. Trapezoid head. Pellet ears. Pinched nose. Triangular beard. Short helmet with flattened top. Shawl indicated. Black border on base. Red-brown clay. Light slip, partly turned red. Right arm missing. Mended at neck'' (MM description).	"Reference-figurine" A.I. 739. Since A.I. 739 is similar to A.I. 145 and this is similar to A.I. 586, explicitly attributed to Type 5, therefore A.I. 740 can be attributed to Type 5. A.I. 586 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 193 gr
76	A.I. 741 	"Statuette as no. 73; longer, rounded beard. Nose, left shoulder, waist, and base broken. Traces of black colour on body. Black border on base. Red-brown clay; reddish slip. Height 24.4. L11 94.7'' (Gjerstad et al. 1935: 695).	"Reference-figurine" A.I. 73 There are no signs of breaks Weight N/A

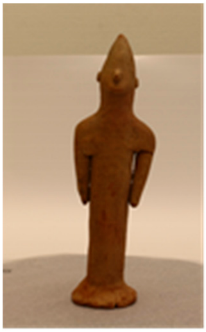
77	A.I. 759 	“Statuette as no. 79; short, rounded beard. Reddish slip. Height 25.3. L11 94.7’’ (Gjerstad et al. 1935: 695) “Statuette with solid, cylindrical body. Splayed base. Sloping shoulders. Vertical arms without shaped hands. Square head. Pinched nose. Pellet ears. Short rounded beard. Conical helmet. Shawl indicated. Brown clay, reddish slip. The statuette was part of the MMs permanent Cyprus Exhibition 1989-2005 at Röhsska Konstslöjdmuseet, Gothenburg’’ (MM description)	“Reference-figurine” A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 759 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 362 gr
78	A.I. 760 	“Statuette as no. 221. Traces of black colour on eyes, beard, and hair, curved black lines over breast; horizontal lines at elbows and waist. Red-brown clay, light slip. Height 23.1. L11 94.7’’ (Gjerstad et al. 1935: 695) “Statuette with solid cylindrical body. Splayed base. Flattened chest. Sloping shoulders. Arms along sides. Hands not shaped. Square head. Pellet ears. Pinched nose. Short beard. Conical helmet. Shawl indicated. Traces of black colour on eyes and beard. Curved black lines over breast. Horizontal lines at elbows and waist. Red-brown clay. Light slip. Needs support. Right arm mended. Modern drill-hole for mounting on underside of base’’ (MM description)	“Reference-figurine” A.I. 221 Weight: 252 gr
79	A.I. 834 	“Statuette with cylindrical, solid body, square head, projecting, curved nose; pellet ears; long, rounded beard, band around head falling down back of head indicating hair; both arms advances holding a flute, now missing. Beard chipped. Slip mostly turned reddish. Height 17.3. K10 98.5’’ (Gjerstad et al. 1935: 697)	No “reference-figurine” Weight: 186 gr

80	A.I. 883 	"Statuette as no. 53. Height 21.6. L10 94.7'' (Gjerstad et al. 1935: 699)	"Reference-figurine" A.I. 53 Weight N/A Black hair and eyes; three parallel lines at neck; ladder pattern on shoulders/shawl; three parallel lines at waist; line along both body sides; line around base.
81	A.I. 886 	"Statuette as no. 73. Height 26.0. L9 99.4'' (Gjerstad et al. 1935: 699).	"Reference-figurine" A.I. 73 Weight: 302 gr
82	A.I. 888 	"Statuette as no. 53. Black beard, red ears, black hair and eyes; lines along shoulders and body; neck-line; angular lines and horizontal lines over breast, three transverse lines at waist. Height 19. 8. L9 99.4'' (Gjerstad et al. 1935: 699). "Statuette with tubular, wheel-made body. Splayed base. Flattened breast. Horizontal shoulders. Arms along sides. Hands not shaped. Long neck. Small moulded head, made separately. Modelled features include ears, eyebrows, nose and mouth. Egyptian style headdress or wig reaching down to middle of neck. Shawl indicated straight edge across breast. Black colour on headdress and left eye. Black line around neck. Angular and horizontal lines on breast. Black lines along shoulders and along sides of body. Three transverse lines at waist. Light-brown clay. Light-brown slip. 1992-02-19 taken to pigment analysis by Gloria Ikosi. Needs mounting. Grupp 1. Rear and right parts of base missing'' (MM description)	"Reference-figurine" A.I. 53 Weight: 193 gr Hair and beard painted black; line round neck and two lines creating v pattern around neck; line n shoulders; maybe two lines at border of shawl; three faded lines at waist; faded line along body sides on the back of the arms.

83	A.I. 895 	"Statuette with body as no. 42, slightly splayed base; straight shawl falling over both shoulders, across breast, trapezoid head; nose and ears roughly shaped; short rounded beard; head uncovered. Hair, eyes, eyebrows, moustache, and beard painted black; red horizontal lines on shawl; red neck-line, arms red with black border lines; black vertical lines along sides of body, belt of black latticed band bordered by black lines around waist, black border on base. Brown clay; light slip. Height 21.7. L9 99.4'' (Gjerstad et al. 1935: 699)	"Reference-figurine" A.I. 42. Since A.I. 42, is explicitly attributed to Type 6 (Gjerstad et al. 1935: CCXXXI, 11), also A.I. 895 can be attributed to Type 6. A.I. 42 is included by Fourrier in the stylistic sub-group of the 'Imports from Idalion' (Fourrier 2007: 91, 131). Weight: 337 gr
84	A.I. 981 	"Statuette as no. 509. Height 16.0. L10 99.6'' (Gjerstad et al. 1935: 703).	"Reference-figurine" A.I. 509. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79 ("reference figurine" of A.I. 509), therefore A.I. 981 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 137 gr
85	A.I. 984 	"Statuette as no. 138; trapezoid head; very short beard, short, straight helmet. Traces of black and red colour on helmet, painted border at base. Broken at neck; right arm missing. Red-brown clay; light slip. Height 20.3. L10 99.6'' (Gjerstad et al. 1935: 703) "Statuette with solid, cylindrical body. Slightly splayed base. Flattened breast. Horizontal shoulders. Arms along sides. Hands flattened. Trapezoid head. Pellet ears. Pinched nose. Short rounded beard. Conical helmet. Shawl indicated with straight edge across breast. Traces of black border on base. Light-brown clay. Light slip'' (MM description)	"Reference-figurine" A.I. 138 Weight: 186 gr Right arm is missing.

86	A.I. 1128 	"Statuette as no. 96; longer, rounded beard. No traces of paint. Height 19.6. L11 94.1'' (Gjerstad et al. 1935: 711).	"Reference-figurine" A.I. 96 Weight: 207 gr Attached beard. Small trace of black on the base front (soot?)
87	A.I. 1205 	"Statuette as no. 52. Traces of colour. Light slip. Height 19.3. L10 94.1'' (Gjerstad et al. 1935: 716).	"Reference-figurine" A.I. 52 Weight: 188 gr Attached beard. No traces of colours visible today.
88	A.I. 1235 	"Statuette as no. 52; triangular, rounded beard. Broken neck and base. Height 19.2. L10 94.1'' (Gjerstad et al. 1935: 716).	"Reference-figurine" A.I. 52 Weight: 194 gr Attached beard.

89	A.I. 1250 	“Statuette as no. 52. Height 20.7. L10 94.1’’ (Gjerstad et al. 1935: 717) “Statuette with tubular, wheel-made body. Splayed base. Flattened breast. Rather horizontal shoulders. Arms along sides. Hands not shaped. Small moulded head made separately. Sloping forehead. Back of head is flat. Long neck. Modelled features include eyes, nose, mouth and ears. Egyptian style wig or headdress falls in compact mass down the back of head and along the sides. Black colour on hair, beard and eyes. Three angular lines around neck. Two horizontal lines across breast. Black lines along shoulders and arms. Broad vertical ladder-pattern along each side of body. Double ladder-pattern at waist. Black border on base. Brick-red clay. Light slip. Height. 18.8 Safely identified as A.I. 1250 through old pic C.6104, though description in SCE does not mention decorations. Grupp 1. Mended at neck’’ Firing crack in right armpit (MM description).	“Reference-figurine” A.I. 52 Weight: 188 gr Hair, eyes and beard painted black. Three angular lines creating V pattern on the neck; two horizontal parallel black lines on the shawl front; line on along shoulders and arms (the left one is visible while the right one is clear only on the shoulders); double ladder pattern at waist; ladder pattern along both body sides; faded line around front base
90	A.I. 1304 	“Statuette as no. 79. Height 17.5. L10 94.1’’ (Gjerstad et al. 1935: 718) “Statuette with solid, cylindrical body. Splayed base. Flattened breast. Sloping shoulders. Arms along sides. Hands not shaped. Oval head. Pellet ears. Pinched nose. Short beard. Short helmet. Red-brown clay. Light slip. Complete. Modern drill-hole for mounting on underside of base. Modern traces of light blue colour on back’’ (MM description)	“Reference-figurine” e A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 1304 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named ‘Soloi A.1’ (Fourrier 2007: 90, 127). Weight: 182 gr

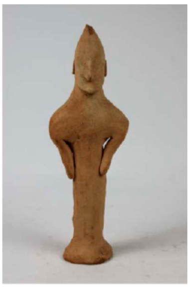
91	A.I. 1337 	"Statuette as no. 218; trapezoid head; short, rounded bears. Black border at base. Height 22.5. K-L: 10-11 94.1" (Gjerstad et al. 1935: 720) "Statuette with solid, cylindrical body. Splayed base. Flattened breast. Sloping wide shoulders. Vertical arms without modelled hands. Trapezoid head. Pinched nose. Pellet ears. Short rounded beard. Conical helmet. Shawl indicated. Fainted black border at base. Red-brown clay, reddish slip. Needs support (cracks in base.) Left arm mended. Cracked on underside of base. (MM description)	"Reference-figurine" A.I. 218. Weight: 363 gr
92	A.I. 1342 	"Statuette as no. 79. Height 22.7. L10 94.1" (Gjerstad et al. 1935: 720) "Statuette with solid, cylindrical body. Splayed base. Sloping, wide shoulders. Vertical arms with undigitated hands. Square head. Pinched nose. Pellet ears. Short, rounded beard. Short, conical helmet. Red-brown clay, light slip. Top of helmet chipped" (MM description)	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 1342 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 340 gr
93	A.I. 1485 	"Statuette as no. 96; only traces of paint. Height 19.8. K10 94.1" (Gjerstad et al. 1935: 726)	"Reference-figurine" A.I. 96 Weight: 246 gr Attached beard. Possible trace of black colour on the right side of the head to indicate hair and under the beard

94	A.I. 1535 Type 7 	"Statuette as no. 53. Black lines along shoulders only. Right shoulder broken. Height 17. L9 94.1'' (Gjerstad et al. 1935: 729).	"Reference-figurine" A.I. 53. A.I. 1535 is explicitly attributed to Type 7 (Gjerstad et al. 1935: CCXXXII, 10). A.I. 1535 is included by Fourrier in the stylistic sub-group derived from a 'Kitian production (Import from Lapithos?)' (Fourrier 2007: 91, 131). Weight. 188 gr Hair, and eyes painted black; two black parallel lines around neck; line along shoulders (right one is more visible than the left one); three parallel lines at waist; two vertical parallel lines along both body sides; possible band at base.
95	A.I. 1572 	"Statuette as no. 79, short, rounded beard. Black border at base. Reddish slip. Height 22.0. L9 93.1'' (Gjerstad et al. 1935: 732).	"Reference-figurine" A.I. 79. Since A.I. 399, explicitly attributed to Type 5, is similar to A.I. 79, therefore A.I. 1572 can be attributed to Type 5. A.I. 399 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight N/A
96	A.I. 1590 	"Statuette as no. 269; trapezoid head; longer, thick, triangular beard. Red-brown clay; light slip. Height 24.4. L9 93.1'' (Gjerstad et al. 1935: 732).	"Reference-figurine" A.I. 269. Since A.I. 1258, explicitly attributed to Type 5, is similar to A.I. 269, therefore A.I. 590 can be attributed to Type 5. A.I. 1258 is included by Fourrier in the stylistic sub-group named 'Soloi A.1' (Fourrier 2007: 90, 127). Weight: 290 gr

97	A.I. 1660 	“Statuette as no. 111; only traces of colour. Height 20.0. L8 94.9” (Gjerstad et al. 1935: 734).	“Reference-figurine” A.I. 52 A.I. 111 is in turn similar to A.I. 52. Weight: 266 gr In the Plan XXVIII the statuettes is represented as fragmented. Possible traces of black on hair; possible line around neck; trace of faded black line on the left shoulder; possible three lines at waist; very faded remains of ladder pattern on both sides of the body.
98	A.I. 1868 	“Statuette as no. 145; short, rounded beard. Height 21.4. M9 94.0” (Gjerstad et al. 1935: 744).	“Reference-figurine” A.I. 145. Since A.I. 586, explicitly attributed to Type 5, is similar to A.I. 145, therefore A.I. 1868 can be attributed to Type 5. A.I. 1871 is included by Fourrier in the stylistic sub-group derived from a ‘Kitian production (Import from Lapithos?)’ (Fourrier 2007: 91, 131). Weight: 214 gr

99	A.I. 1871 	“Statuette as no. 86: rather long, rounded beard; both arms bent over breast holding quadruped. Hair painted black; black lines along shoulders, arms, and sides of body; transverse lines at waist; red body and face. Height 20.0. M9 94.0” (Gjerstad et al. 1935: 711, CCXXXII, 11). “Tall, hollow, cylindrical, wheel-made body; both arms bent over breast, holding an animal; moulded head made separately; sloping forehead; curved, small nose; long, slightly pointed beard; large ears; hair in compact mass down the back of head and along the sides. Hard, buff clay. Red paint all over. Traces of black paint on back of head and along left side of body. Mended at neck. Paint worn. The statuette was exhibited at Röhsska Konstslöjdmuseet, Gothenburg, 1992-02-19 taken to pigment analysis by Gloria Ikosi. Grupp 1. Ø of base 5.9 cm” (MM description)	“Reference-figurine” A.I. 86. A.I. 1871 is explicitly attributed to Type 7 (Gjerstad et al. 1935: CCXXXII, 11) Weight: 206 gr Small traces of black on the head back; possible faded black line on the back; traces of red colour all over the face, the body and on the animal. The black decoration mentioned by the SCE are not more visible today.
100	A.I. 3893 	The MM assigned to the statuette a new number (A.I. 3893). It is believed that the object is the A.I. 52.	A.I. 52? Weight: 229 gr Traces of black colour on the hair and possibly for the beard (some spots); possible trace of line on the left shoulder; possible lines at waist; traces of ladder pattern on both sides of the body.

Table 4.
Small figurines sampled at Malmö Konstmuseum.

ID	INVENTORY NO.	LITERATURE DESCRIPTION AND MUSEUM INFORMATION	NEW INFORMATION AND COMMENTS (Vassallo©)
101	A.I. 870 (MM 25252) 	"Statuette as no. 52. Hair and eyes are painted black; black neck-line; angular lines over breast; black lines along shoulders and arms; bands of ladder-pattern along sides of body; three transverse lines at waist; a black border on base. Broken neck. Height 18.5 cm. L 10 94.7" (Gjerstad et al. 1935: 698) "Statuette of yellowish terracotta attributed to unknown artist and dated to 600-450 BC. Height 18.3'' (Malmö Konstmuseum catalogue).	"Reference-figurine" A.I. 52 Weight: 176 gr Hair and eyes painted black; possible black line at neck; (two?) black lines creating V pattern at neck; possible black line along shoulders and arms; three parallel black lines at waist; ladder pattern along both body sides; band around front base.
102	A.I. 1929 (MM 25250) 	"Statuette as no. 218; longer, rounded beard. Top of helmet damaged. Black border at base. Height 22.8. M9 94.0" (Gjerstad et al. 1935: 746). "Statuette of yellowish terracotta attributed to unknown artist and dated to 600-450 BC. Height 22.5'' (Malmö Konstmuseum catalogue).	"Reference-figurine" A.I. 218. A.I. 218 is similar to A.I.118. A.I.118 has no further reference figurine and therefore no mentions to the similarity nor with A.I.73 nor with A.I.79 Weight: 347 gr
103	A.I. 1962 (MM 25251) 	"Statuette as no. 79; short, straight-cut beard. Black border at base. Slip partly turned red-brown. Height 25.2. M9 94.0" (Gjerstad et al. 1935: 747). "Statuette of yellowish terracotta attributed to unknown artist and dated to 600-450 BC'' (Malmö Konstmuseum catalogue).	"Reference-figurine" A.I. 79 Weight: 328 gr

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