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METHOD ARTICLE

Faces Revealed Project and ancient Egyptian yellow coffins: A new methodology step-by-step

[version 1; peer review: 4 approved]

Stefania Mainieri [1,2]

[1]Fondazione Museo Egizio, Torino, Torino, 10123, Italy
[2]Near Eastern Languages & Cultures - UCLA, The University of California, Los Angeles, California, 90095, USA

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Abstract

Faces Revealed Project established a new methodology for studying the geometry of the human forms and facial features realized on anthropoid yellow coffins of Ancient Egypt. Since 1980, yellow coffins have been the subject of various studies mainly focused on iconography and palaeography. However, these anthropoid coffins are three-dimensional objects with well-rendered masks and detailed facial features as well as forearms, hands and bellies. This lack of analysis in the study of coffins may be due to the fact that they are "concealed" by rich and multi-coloured decoration, so they are not easily visible in all their forms to the naked eye. Today new technologies allow us to go more in-depth and digitally switch off the decoration and observe these "invisible" features. As this is an entirely new process, the primary task of the Faces Revealed Project was to establish a new methodology from the photogrammetric survey to the data collection.

The present article discusses in detail the stages of the Project applied to around 100 Egyptian yellow coffins stored in Museums in Europe, the United States and Egypt and the information that they can disclose. The task is to share with the scientific community the established protocol and offering the possibility to "work independently" applying the same methodology to the same objects as well as to other classes of material.

Keywords

Ancient Egypt, yellow coffins, photogrammetry, 3D models, decoration, geometry, facial features

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1. **Andrea D'Andrea**, Università degli Studi di NAPOLI "L'Orientale", Naples, Italy
2. **Mona Hess**, University of Bamberg, Bamberg, Germany
3. **Willeke Wendrich**, Politecnico di Torino, Turin, Italy
University of California Los Angeles College of Letters and Science (Ringgold ID: 118546), Los Angeles, USA
4. **Caroline Arbuckle MacLeod**, St Thomas More College, Saskatchewan, Canada

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Corresponding author: Stefania Mainieri (stefaniamainieri@gmail.com)

Author roles: Mainieri S: Conceptualization, Investigation, Methodology, Project Administration, Supervision, Validation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

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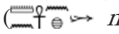
Introduction

Called yellow due to the colour of their background, imitating gold, yellow coffins appeared in Thebes at the end of the New Kingdom (proto-yellow type, from 1279 BCE ca.) and were used for more than a millennium peaking during the 21st Dynasty (1069–945 BCE ca.)[1]. This type of coffin was crafted in wood and anthropoid in shape, with a detailed rendering of the human forms in the upper part of the lid. They were used in nested funerary assemblages comprising one or two coffins ()[2] with their lids and cases: a larger outer coffin () *mn anx*)[3] containing the inner coffin () *swH.t*)[4] that hosted the mummy of the deceased. The "assemblage" of yellow coffins included also a third element, the distinctive part of the yellow coffin type, the mummy board, a flat and small version of the lid placed directly onto the mummy[5].

The main characteristic of this type of coffin is the decoration. A coating of varnish over a rich polychrome decoration - characterised by a complete filling of all the empty spaces (horror vacui) - cover both the coffin's external and internal parts. While the pictorial areas on the coffins show a high degree of iconographic autonomy, they are combined into a layout that forms a carefully planned "topography"[6]. In the Third Intermediate Period (1069–664 BCE ca.) the pictorial and textual tradition of the tomb walls found its way onto the coffins, which came to simultaneously perform the function of the tomb and the temple, thus replacing the burials of earlier periods. We are therefore witnessing what van Walsem calls the "architectonisation" of the coffin. This entails the coffin becoming a small universe, at the centre of which there is the deceased himself, who becomes the source of his own regeneration and rebirth[7].

As is easy to understand, images and texts have always been the focus of the numerous studies on yellow coffins, considered the main "diagnostic features" of coffins development between the late New Kingdom and Late Period[8]. Since the beginning they have been catalogued, typologised and dated by the scholars only on the base of their "Visual appearance"[9]. The first typology of yellow coffins was made by Andrzej Niwinski in 1988. He collected more than 400 coffins across 88 museums, identifying the yellow type's fundamental characteristics and proposing a typology on the basis of their decoration and layout[10]. Over the years this fundamental work has been revisited by different scholars such as Rogerio Sousa, Kathlyn Cooney or International Projects, i.e. the Vatican Coffin Project and the Fitzwilliam Museum's Ancient Egyptian Coffins Project[11]. The new studies have been focused on correcting some problems in the formal definition of Niwinski's typology[12] and the necessity to create a more precise typology including the ancient reuse of these objects which also led to more in-depth social, economic and religious perspectives[13]. Furthermore, their materiality has oriented the research to the constituent materials, such as the composition of wood and pigments or the assembly techniques used by artists and craftsmen[14].

Still, none of these recent works focused on another fundamental element of the yellow coffin, its anthropoid form which represents the "missing piece" in the Egyptological study of yellow coffins. These coffins, in fact, symbolise the replacement body for the dead[15]. Shoulders, elbows, forearms, hands, as well as masks with detailed facial features are depicted three-dimensionally. Faces in fact are not only painted on coffins but carefully carved or modelled to allow the deceased to "see, taste, and smell the living world"[16]. Different from a rectangular coffin, we cannot fail to consider the forms and the geometry of these objects, as well as the way and the style in which the human forms and facial features were crafted. We need to approach this material in the same way as statues and analyse in detail these elements that, if added to the information we already have on these coffins, could help to identify common "hands" or specific stylistic features, clarifying their chronology, especially in the light of the massive reuse of these objects in ancient times[17].

Approaching the study of forms and geometry on a polychrome, over-decorated three-dimensional object is hard

[1] For yellow coffins see Niwiński, 1988; Sousa, 2020a; Taylor, 1985; van Walsem, 1997

[2] Wb 1, 379.7; https://thesaurus-linguae-aegyptiae.de/lemma/51000, in: *Thesaurus Linguae Aegyptiae* (accessed: 2/28/2024)

[3] Wb 2, 63.1; https://thesaurus-linguae-aegyptiae.de/lemma/69970, in: *Thesaurus Linguae Aegyptiae* (accessed: 2/28/2024).

[4] Wb 4, 74.4; https://thesaurus-linguae-aegyptiae.de/lemma/130650, in: *Thesaurus Linguae Aegyptiae* (accessed: 2/28/2024)

[5] Sousa, 2020a

[6] Sousa, 2017; Sousa, 2018a; van Walsem, 1997

[7] van Walsem, 1997

[8] Taylor, 2001

[9] Niwiński, 1988; Niwiński, 1989; Niwiński, 2000; Niwiński, 2018; Sousa, 2018a; Sousa, 2018b; Sousa, 2020a; Taylor, 1985; van Walsem, 1997

[10] Niwiński, 1988

[11] Amenta, 2014; Amenta & Guichard, 2017; Amenta *et al.*, 2010; Dawson & Strudwick, 2019; Dawson & Turmezei, 2020; Strudwick & Dawson, 2016. See also the web page of the Project https://fitzmuseum.cam.ac.uk/research/projects/ancient-egyptian-coffins

[12] Sousa, 2017; Sousa, 2018a; Sousa, 2018b; Sousa, 2020b

[13] Cooney, 2007; Cooney, 2014; Cooney, 2017; Cooney, 2018a; Cooney, 2020; Cooney, 2021

[14] Amenta, 2014; Amenta & Guichard, 2017; Amenta *et al.*, 2010; Dawson, 2018; Dawson *et al.*, 2016; Dawson & Strudwick, 2019; Dawson & Turmezei, 2020

[15] Cooney, 2015

[16] *Ibidem*

[17] Kathlyn Cooney demonstrated that more than 60% of yellow coffins were reused in ancient times and that the usurpation of coffins was a fairly widespread practice in Egypt during the Third Intermediate Period (1069-664 BC ca.) especially across the 21st to 22nd dynasties. For reuse of yellow coffins see Cooney bibliography especially Cooney, 2007; Cooney, 2017; Cooney, 2020; Cooney, 2023

because the Visual appearance covers its Physical geometry and an objective analysis of forms cannot be made by the naked eye. This limit in geometrical analyses can be overcome today thanks to the digital technologies and 3D modelling. The main instrument of the project is Photogrammetry and its ability to create a real and submillimetric digital reproduction of an object with bi-dimensional images. The resultant 3D model allows us to observe the coffin with and without decoration and analyse the forms accurately without "visual interference". The ability to create two different visualisations of the same object became the main instrument and the first step of the Faces Revealed Methodology, followed by the possibility to add and overlap in transparency other "layers" mapping both the decoration and the geometry on the model[18].

The research is divided into different workpackages and follows a specific methodology: from photogrammetric acquisition to the creation of "layers" and the morphometric approach, data connection and grouping. Starting from the creation of high-resolution and submillimetric photogrammetric models of coffins will be explained in detail all the steps of the methodology and the numerous elements that this analysis can disclose[19].

Methods

The corpus

The *corpus* of yellow coffins analysed by the Faces Revealed Project consists of more than 100 coffin lids stored in 10 Museums in America, Europe and Egypt (Table 1)[20]. The museums' Partners were selected on the basis of

[18] https://facesrevealed.museoegizio.it/

[19] The present article is a supplementary and extensive description of the Faces Revealed Methodology and its preliminary results, in continuity with the short paper presented by the author at the beginning of the Project, Mainieri *et al.*, 2022 (https://isprs-archives.copernicus.org/articles/XLVI-2-W1-2022/335/2022/).

[20] Museo Egizio, Torino (Italy); Musei Vaticani (Città del Vaticano); Rijksmuseum van Oudheden (RMO), Leiden (The Netherlands); Musée du Louvre, Paris (France); "Museo Egizio" di Firenze (Italy); Museo Archeologico Nazionale di Napoli (MANN) (Italy), Metropolitan Museum (MET), New York (USA); Egyptian Museum, Cairo (EMC) (Egypt); Los Angeles County Museum of Art (LACMA) (USA); National Museum of Egyptian Civilisation, Cairo (NMEC), (Egypt).

Table 1. Corpus of the selected yellow coffins.

Museum	Inv. N.	Owner/s	Part of Coffin	Dynasty	Provenance
"Museo Egizio" di Firenze	8521	Ankhsenmut	Mummy Board	21st Dynasty, Middle	Bab el-Gasus Cache
"Museo Egizio" di Firenze	8523	Ankhsenmut	Outer Lid	21st Dynasty, Middle/ Late	Bab el-Gasus Cache
"Museo Egizio" di Firenze	8524	Djedmutiuesankh	Outer Lid	21st Dynasty	Bab el-Gasus Cache
"Museo Egizio" di Firenze	8528	Djedmutiuesankh	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
"Museo Egizio" di Firenze	9534	Djedmutiuesankh	Mummy Board	21st Dynasty, Late	Bab el-Gasus Cache
"Museo Egizio" di Firenze	8527	Khonsumes	Inner Lid	21st Dynasty, Middle	Bab el-Gasus Cache
"Museo Egizio" di Firenze	9530	Khonsumes	Mummy Board	21st Dynasty, Middle	Bab el-Gasus Cache
"Museo Egizio" di Firenze	2174	Anonymous	Mummy Board	21st Dynasty, Middle	Thebes (?)
"Museo Egizio" di Firenze	2157	Anonymous	Inner Lid	21st Dynasty, Middle	Thebes (?)
"Museo Egizio" di Firenze	7450	Pashuemipet	Inner Lid	21st Dynasty, Early	Thebes (?)
"Museo Egizio" di Firenze	9476	Tauhenut	Mummy Board	21st Dynasty, First half	Bab el-Gasus Cache
Egyptian Museum, Cairo	CG 6128	Anonymous	Mummy Board	21st Dynasty, Middle	Bab el-Gasus Cache
Egyptian Museum, Cairo	CG 6146	Anonymous	Outer Lid	21st Dynasty, Middle	Bab el-Gasus Cache
Egyptian Museum, Cairo	CG 6010	Pashedkhonsu	Outer Lid	21st Dynasty, Middle/ Late	Bab el-Gasus Cache
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2222	Bakenkhonsu	Inner Lid	21st Dynasty, Late	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2237/01	Butehamon	Inner Lid	21st Dynasty, Middle	Deir el-Medina (TT 291?)

Museum	Inv. N.	Owner/s	Part of Coffin	Dynasty	Provenance
Fondazione Museo delle Antichità Egizie di Torino	Cat. 223/03	Butehamon	Mummy Board	21st Dynasty, Middle	Deir el-Medina (TT 291?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2236/01	Butehamon	Outer Lid	21st Dynasty, Middle	Deir el-Medina (TT 291?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2212	Hori	Inner Lid	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2212/01	Hori	Mummy Board	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	S 7715/01	Horpaenaset	Inner Lid	21st Dynasty, Middle	Deir el-Medina
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2238/01	Khonsumes	Inner Lid	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2238/03	Khonsumes	Mummy Board	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	S 7715/02	Mutemperamun	Mummy Board	21st Dynasty, Middle	Deir el-Medina
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2219/01	Anonymous	Inner Lid	21st Dynasty, Late	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2219	Anonymous	Mummy Board	21st Dynasty, Late	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2226/02	Tabakenkhonsu	Inner Lid	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2226/01	Tabakenkhonsu	Mummy Board	21st Dynasty, Middle	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2228/01	Tamutmutef	Inner Lid	21st Dynasty, Late	Thebes (?)
Fondazione Museo delle Antichità Egizie di Torino	Cat. 2228/02	Tamutmutef	Mummy Board	21st Dynasty, Late	Thebes (?)
Los Angeles County Museum of Art	M.41.3a	Anonymous	Inner Lid	21st Dynasty, Middle	Thebes (?)
Los Angeles County Museum of Art	M.41.3c)	Anonymous	Mummy Board	21st Dynasty, Middle	Thebes (?)
Metropolitan Museum of Art, New York	17.2.7b.1	Amenhotep	Inner Lid	22nd Dynasty, Early	Sheikh Abd el-Gurna
Metropolitan Museum of Art, New York	17.2.7a.1	Amenhotep	Outer Lid	22nd Dynasty, Early	Sheikh Abd el-Gurna
Metropolitan Museum of Art, New York	26.3.4a	Ansenmes	Inner Lid	20th- 21st Dynasty	Deir el-Bahri (Pit 219)
Metropolitan Museum of Art, New York	26.3.8	Gautsoshen	Mummy Board	21st Dynasty, Late	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.183a	Henuttawy	Inner Lid	21st Dynasty, Middle	Thebes (TT 59)
Metropolitan Museum of Art, New York	25.3.184	Henuttawy	Mummy Board	21st Dynasty, Middle	Thebes (TT 59)
Metropolitan Museum of Art, New York	25.3.182a	Henuttawy	Outer Lid	21st Dynasty, Middle	Thebes (TT 59)
Metropolitan Museum of Art, New York	86.1.5a	Iineferty	Inner Lid	19th Dynasty	Deir el-Medina (TT 1)
Metropolitan Museum of Art, New York	86.1.5c	Iineferty	Mummy Board	19th Dynasty	Deir el-Medina (TT 1)

Museum	Inv. N.	Owner/s	Part of Coffin	Dynasty	Provenance
Metropolitan Museum of Art, New York	26.3.1a	Iotefamun	Outer Lid	21st Dynasty, Early	Thebes (Pit 1016)
Metropolitan Museum of Art, New York	86.1.2a	Khonsu	Inner Lid	19th Dynasty	Deir el-Medina (TT 1)
Metropolitan Museum of Art, New York	86.1.1a	Khonsu	Outer Lid	19th Dynasty	Deir el-Medina (TT 1)
Metropolitan Museum of Art, New York	25.3.8a	Menkheperra	Inner Lid	21st Dynasty, Middle	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.9	Menkheperra	Mummy Board	21st Dynasty, Middle	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.7a	Menkheperra	Outer Lid	21st Dynasty, Middle	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.11a	Tabakmut	Inner Lid	21st Dynasty, Middle/ Late	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.12	Tabakmut	Mummy Board	21st Dynasty, Middle/ Late	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.10a	Tabakmut	Outer Lid	21st Dynasty, Middle/ Late	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.15a	Tiye	Inner Lid	21st Dynasty, Middle	Thebes (TT 60)
Metropolitan Museum of Art, New York	25.3.16	Tiye	Mummy Board	21st Dynasty, Middle	Thebes (TT 60)
Musée du Louvre, Paris	AF 9592	Aafenhor	Inner Lid	21st Dynasty, Middle	Akhmim (?)
Musée du Louvre, Paris	E 13030	Amenhotep	Inner Lid	21st Dynasty, Late	Thebes (?)
Musée du Louvre, Paris	E 13041	Amenhotep	Mummy Board	21st Dynasty, Late	Thebes (?)
Musée du Louvre, Paris	E 13028	Amenhotep	Outer Lid	21st Dynasty, Late	Thebes (?)
Musée du Louvre, Paris	E 27460	Bakenmut	Inner Lid	22nd Dynasty	Thebes (?)
Musée du Louvre, Paris	E 13047	Nebhep	Mummy Board	21st Dynasty, Early	Deir el-Medina (?)
Musée du Louvre, Paris	AF 9590	Anonymous	Inner Lid	21st-22nd Dynasty	Thebes (?)
Musée du Louvre, Paris	E 10636	Anonymous	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Musée du Louvre, Paris	E 10636	Anonymous	Outer Lid	21st Dynasty, Late	Bab el-Gasus Cache
Musée du Louvre, Paris	E 13036	Anonymous	Inner Lid	21st Dynasty, Middle	Thebes (?)
Musée du Louvre, Paris	E 13045	Anonymous	Inner Lid	21st-22nd Dynasty	Thebes (?)
Musée du Louvre, Paris	18840	Anonymous	Inner Lid	21st-22nd Dynasty	Thebes (?)
Musée du Louvre, Paris	18840	Mererimenna	Mummy Board	21st-22nd Dynasty	Thebes (?)
Musée du Louvre, Paris	E 3859	Anonymous	Mummy Board	21st Dynasty, Middle	Thebes (?)
Musée du Louvre, Paris	E 13029	Panebmonthu	Inner Lid	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	E 13046	Panebmonthu	Mummy Board	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	E 20165	Paser	Mummy Board	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	N 2581	Paser	Outer Lid	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	N 2610	Sutymes	Inner Lid	21st Dynasty, Early	Deir el-Medina (?)
Musée du Louvre, Paris	N 2611	Sutymes	Mummy Board	21st Dynasty, Early	Deir el-Medina (?)
Musée du Louvre, Paris	N 2609	Sutymes	Outer Lid	21st Dynasty, Early	Deir el-Medina (?)

Museum	Inv. N.	Owner/s	Part of Coffin	Dynasty	Provenance
Musée du Louvre, Paris	N 2571	Tamutneferet	Inner Lid	19th Dynasty	Sheikh Abd el-Gurna
Musée du Louvre, Paris	N 2620	Tamutneferet	Mask	19th Dynasty	Sheikh Abd el-Gurna
Musée du Louvre, Paris	N 673	Tamutneferet	Outer Lid	19th Dynasty	Sheikh Abd el-Gurna
Musée du Louvre, Paris	E 13035	Tanethereret	Mummy Board	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	E13034	Tanethereret	Inner Lid	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	E13027	Tanethereret	Outer Lid	21st Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	N 2562	Tanetimen	Inner Lid	21st Dynasty, Middle	Deir el-Medina (?)
Musée du Louvre, Paris	N 2612	Tanetshedmut	Inner Lid	22nd Dynasty, Early	Thebes (?)
Musée du Louvre, Paris	E 18843	Tchanefer	Inner Lid	21st Dynasty, Middle	Thebes (?)
Musei Vaticani, Città del Vaticano	25003.2.1	Amenhotep	Inner Lid	21st-22nd Dynasty	Thebes (?)
Musei Vaticani, Città del Vaticano	D 2066.2.1	Anet	Inner Lid	20th- 21st Dynasty	Deir el-Medina/ Akhmim (?)
Musei Vaticani, Città del Vaticano	25012.2.1	Djedhoriuefankh	Outer Lid	22nd Dynasty, Early	Thebes (?)
Musei Vaticani, Città del Vaticano	25008.2.1	Djedmut	Outer Lid	21st-22nd Dynasty	Thebes (?)
Musei Vaticani, Città del Vaticano	25035.3.2	Ikhy	Mummy Board	21st Dynasty, Middle/ Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	25035.3.1	Ikhy	Outer Lid	21st Dynasty, Middle/ Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	25016.2.1	Anonymous	Inner Lid	21st Dynasty, Middle/ Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	51515	Anonymous	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	25020	Anonymous	Mummy Board	21st Dynasty, Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	25022	Anonymous	Mummy Board	21st Dynasty, Late	Bab el-Gasus Cache
Musei Vaticani, Città del Vaticano	25015.2.1	Takhybiat	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Museo Archeologico Nazionale di Napoli	2348	Nesra	Inner Lid	22nd Dynasty, Early	Thebes (?)
Museo Archeologico Nazionale di Napoli	2347	Anonymous	Inner Lid	21st-22nd Dynasty	Thebes (?)
National Museum of Egyptian Civilization	CG 61011	Padiamon	Inner Lid	19th-20th Dynasty	Royal Cache (TT 320)
Rijksmuseum van Oudheden, Leiden	AMM18-g	Ankhefenkhonsu	Outer Lid	22nd Dynasty, Early	Thebes (?)
Rijksmuseum van Oudheden, Leiden	AMM18-h	Djedmonthuiufankh	Inner Lid	22nd Dynasty, Early	Thebes (?)
Rijksmuseum van Oudheden, Leiden	AH1a	Nesypanebawib	Mummy Board	21st Dynasty, Early	Thebes (?)
Rijksmuseum van Oudheden, Leiden	F 93/10.2b.1	Nesytanebtawy	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Rijksmuseum van Oudheden, Leiden	F 93/10.2a.1	Nesytanebtawy	Outer Lid	21st Dynasty, Late	Bab el-Gasus Cache

Museum	Inv. N.	Owner/s	Part of Coffin	Dynasty	Provenance
Rijksmuseum van Oudheden, Leiden	L1	Anonymous	Inner Lid	21st-22nd Dynasty	Thebes (?)
Rijksmuseum van Oudheden, Leiden	F 93/10.4.1	Anonymous	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Rijksmuseum van Oudheden, Leiden	F 19/31.9.1	Anonymous	Inner Lid	21st Dynasty	Thebes (?)
Rijksmuseum van Oudheden, Leiden	AH 188	Penpy	Mummy Board	22nd Dynasty, Early	Thebes (?)
Rijksmuseum van Oudheden, Leiden	F 93/10.3a	Tentpenherunefer	Inner Lid	21st Dynasty, Late	Bab el-Gasus Cache
Rijksmuseum van Oudheden, Leiden	F 93/10.3b	Tentpenherunefer	Mummy Board	21st Dynasty, Late	Bab el-Gasus Cache

pre-existent collaboration and for their significant yellow coffins collections. Moreover, a conspicuous number of these coffins are under investigation by other International Projects for diagnostic investigation and new Egyptological studies, concerned above all with decoration and palaeography as well as the history and provenance of collections[21]. These in-progress studies and collaborations with different specialists were fundamental in the choice of objects enabling us to combine results with other data acquired from the most current research on yellow coffins[22].

The *corpus* represents a heterogeneous group of objects for provenance, chronology and typology. For the most part we have no secure geographical provenance since they were acquired by private collection at the beginning of the 19th century. Beyond these, are also objects from the Bab el-Gasus Cache, the collective tomb discovered in 1891 close to the temple of Hatshepsut with the burials of 153 priests and priestesses of Amun who lived under the 21st Dynasty (ca. 1069–945 BC)[23]. In this research are included the coffins of the Lot I, stored in the Musée du Louvre in Paris; the Lot V in the "Museo Egizio" di Firenze; the Lot XI in the Rijksmuseum van Oudheden (RMO) in Leiden; the Lot XVII in the Musei Vaticani and the outer coffin of Pashedkhonsu (CG6010) and the anonymous outer coffin with related mummy board (CG6146, CG6128) stored in the Egyptian Museum in Cairo (EMC)[24]. In addition to the Bab el-Gasus Cache, the *corpus* includes coffins from other areas of the Theban Necropolis such as the Royal Cache[25] and tombs in Deir el-Medina.

In this research all the types and subtypes identified by Niwinski in 1988 are considered, covering then the entire period of production/ use of yellow coffins: from the "first well–authenticated examples of coffins of yellow type"[26] in the 19th dynasty - the so called proto yellow coffins from the Tomb of Sennedjem (TT1)[27] - until the beginning of the 22nd dynasty with the *stola* coffins[28].

Photogrammetric protocol and data processing

The aim of the Faces Revealed Project is the construction of high-resolution and submillimetric 3D representations of coffins capable of describing every fine detail with and without texture by means of versatile, transportable and cost-effective instruments and software. For these reasons the photogrammetric approach appeared to be more useful for this project in comparison with a 3D scanner. Even the accuracy of the photogrammetric 3D models depends on many different factors, these can be taken under control and the models can have comparable resolution than the scanners[29] or, at least, meet the needs of the Faces Revealed Project.

[21] Among these are the Vatican Coffin Project and the Gates of Priests Project.

[22] Ongoing research are carried out especially by collaborators of the Vatican Coffin Project: studies on wood (by Victoria Asensi Amòros); iconography (by Jaume Vilarò Frabegat and Rogerio Sousa); palaeography (by Nina Biezeno); imaging tecniques and analyses of different composition of pigments, varnish and other materials (by the CNRS and Louvre, Lucil Brunel and the Centro di Conservazione e Restauro La Venaria Reale); ancient reuse of coffins (by Kathlyn Cooney); new technologies as CT-scans and X-rays (by Musei Vaticani).

[23] The Bab el-Gasus galleries consisting of more than two hundred coffins and nearly a hundred scrolls of papyri, 110 boxes filled with ushabtis, 80 statuettes, various inscribed stelae, along with many other artefacts. A selection of the *Bab el-Gasus* coffins were retained for the Giza Museum and the rest of the objects were divided into 17 lots and in 1893 they were sent by the Khedive of Egypt as his gift to several countries for diplomatic relations. Further relocations occurred and today at least 35 museums are known to house objects from the Bab el-Gasus cache, see Sousa *et al.,* 2021 and related bibliography.

[24] I would like to thank Rogerio Sousa for allowing me to study these coffins that are part of his research.

[25] Inner coffin of Padiamon, NMEC, CG61011.

[26] Taylor, 2001

[27] Haring, 2006; Porter & Moss, 1960, pp. 1–5

[28] van Walsem, 1997

[29] Mandelli *et al.*, 2019

In collaboration with the Department of Architecture, Built Environment and Construction engineering (DABC) of the Politecnico di Milano[30], the first operation was to find the best instruments and methodology[31]. Then, a specific reference protocol for 3D acquisition was developed. The protocol included the possibility of adaptions for different contexts according to museums' conditions.

Faces Revealed Project considers only the external upper part of coffin lids as far down as the lower part of the crossed forearms or, for the *stola* coffins, until the end of the collar (*wesekh*-collar). The coffins were placed in a horizontal position (on the floor or on a table). A full-frame Nikon D750 camera coupled with a Nikkor 35 mm f/1.8 lens was used for the photographic survey. A polariser was mounted on the camera's lens to avoid as much as possible reflections and shiny areas due to the varnish on the coffins. The yellow coffins are in fact covered by an original (*Pistacia* resin) or modern (Paraloid B72)[32] layer of varnish. Ancient or modern, the varnish creates reflections, which could produce a layer of noise and subsequent blunders and incorrect descriptions of the coffin's shape[33]. This issue can be overcome using the polariser[34], which became an essential instrument of the project (see *infra*).

Each image has a maximum resolution of 6016 pixels by 4016 pixels. The camera is always placed on a tripod and the shot is delayed by 5 seconds - using automatic shutter release or a remote control - to prevent vibration. This permits the use of low ISO values (no more than 800) in the low-illuminated museum rooms. The mean calculated Ground Sampling Distance (GSD) of the photogrammetric survey is around 0,2 mm since the pixel pitch is 6 µm and the distance of acquisition from the object is always about 1 m. The acquisition geometry is circular around the object, maintaining the camera as much as possible nadiral to the coffins. The number of images for each artefact is variable considering both the dimension of the objects and a transversal overlap of the images of more than 85% (between 90–150 pics for half coffins until 300 for a full coffin).

Other essential instruments for the photogrammetric survey are two pre-calibrated L-shaped bars. The bars are iron carpenter's squares of 60 and 40 cm, always placed next to the head of each coffin and on the same level (Figure 1). The bars have been equipped with circle and cross non-coded targets fundamental to prevent deformations in the final 3D model. Moreover, these are useful to accurately scale the reconstruction accurate to 0.001(m) and to have a precise reference system that defines the plane on which the orthophotos are then projected.

[30] Department of Architecture, Built environment and Construction engineering (DABC) of Politecnico di Milano is the Secondment of the Faces Revealed Project. I would like to thank Corinna Rossi, Professor of Egyptology at the Politecnico di Milano and Alessandro Mandelli, Specialist Senior Technician at DABC.

[31] Mainieri *et al.*, 2022

[32] Paraloid B72 is a synthetic polymer resin, widely used during the past decades for the consolidation of materials of interest to cultural heritage, applied in particular on wooden artefacts, of which the yellow coffins. Because this resin tends to seep into wood completely obliterating particulars, studies to remove this *strato* of modern material are in progress. For information on Paraloid, I would like to thank Giovanna Prestipino, conservator of the Vatican Coffin Project, and Paola Buscaglia, conservator of the Centro Conservazione e Restauro La Venaria Reale, Torino.

[33] Mandelli *et al.*, 2019

[34] *Ibidem*; Conen *et al.*, 2018; Mainieri *et al.*, 2022



Figure 1. Photogrammetric survey of the lid of Nesra (MANN, inv. n. 2348). The image is courtesy and authorised by the Museo Archeologico Nazionale di Napoli (MANN).

As mentioned, on the basis of the different environments, methods and techniques of data acquisition were adapted at times. The main variables addressed during the survey were linked to: i) the low illumination of the exhibition rooms, ii) the inability to open the display case in which the objects are kept, iii) and the position of the coffins.

For dark rooms two different solutions were applied linked to the use or not of the flash (Yongnuo YN560). A flash synchronised with the camera was used for the inner lid and mummy board of Butehamon in the Museo Egizio, Torino (Cat. 2237/01 and Cat. 2237/03)[35]. Even if the objects were placed outside the showcases and in a horizontal position, the survey was made in the Museum's exhibition room n. 8, a dark area with little and yellow light from the ceiling. Moreover, the colour of the coffins is very dark, and the objects are covered by varnish, creating accentuated reflective surfaces. To reduce the noises, the polariser was used with constant control, image by image, and a manual adjustment, as well as a long and elaborated transformation of pictures by Lightroom were performed.

The second solution adopted was to use the camera mounted on the tripod without flash, using a remote control and a small light switched on only for the time to focus the framed area before releasing the shutter. This setting was the best solution for coffins in dark rooms and for those coffins that are closed in showcases. Taking pictures through the display windows represented the most challenging situation during the present research. Even if the work is quite long both for the survey and for the post processing, the results are functional both in terms of resolution and error (Figure 2).

The protocol developed also had to be adapted when the coffins were placed in a vertical position, and it was not possible to move them from their casing. In this case, the bars were fixed on a tripod using tweezers and placed as close as possible to the object, on one side or in front of it (Figure 3). On one hand this position made it easier to place the camera nadiral to the coffin; on the other hand, due to the narrow spaces, it was not always possible to reach the top and the sides of the object, so sometimes the 3D models lack these portions.

The 3D photogrammetric data elaboration uses the software Agisoft Metashape Professional 1.8.3. and strictly follows the photogrammetric pipeline: i) photo-alignment at high resolution; ii) automatic recognition and manual check of circular and cross non-coded targets; iii) scaling; iv) dense cloud reconstruction in "medium" or "high" quality and data cleaning; v) mesh model in "medium" or "high" quality; vi) texturing; developing high-resolution orthophoto; vii) exporting high-resolution orthophoto textured and non textured[36].

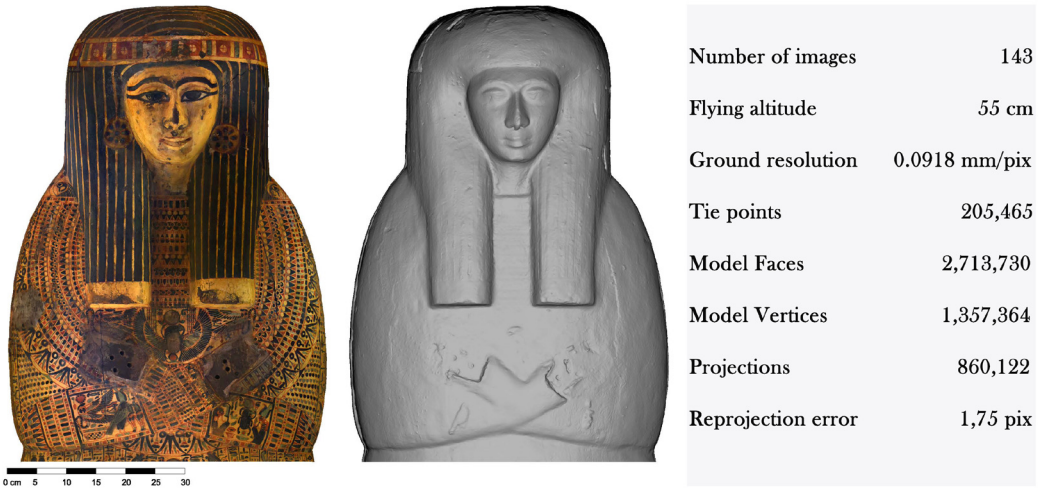
The "construction" of different layers. Comparison, overlapping and results

The 3D models are fundamental since they represent the only way to export identical and high-resolution images of an object, both textured and non textured. These images represent the first two "layers" created for each coffin: the Visual appearance "layer" (the orthophoto with texture – "layer" 1) and the Physical geometry "layer" (the orthophoto without texture – "layer" 2). The extraction of the model in both cases follows the coordinate and the metric system given during the photographic survey[37]. The two models exported

[35] https://collezioni.museoegizio.it/it-IT/material/Cat_2237/?description=butehamon&inventoryNumber=&title=&cgt=&yearFrom=&yearTo=&materials=&provenance=&acquisition=&epoch=&dynasty=&pharaoh=

[36] A free alternative that can perform an equivalent function is Blender software licensed as GNU GPL Version 2 or later (https://www.blender.org).

[37] Mainieri *et al.*, 2022; Mandelli *et al.*, 2019



Number of images	143
Flying altitude	55 cm
Ground resolution	0.0918 mm/pix
Tie points	205,465
Model Faces	2,713,730
Model Vertices	1,357,364
Projections	860,122
Reprojection error	1,75 pix

Figure 2. Textured and non textured orthophoto of the lid of Khonsumes ("Museo Egizio", Firenze, inv. n. 8527). The orthophotos are courtesy and authorised by the Museo Archeologico Nazionale di Firenze (Direzione Regionale Musei della Toscana).



Figure 3. Photogrammetric survey of the lid of Khonsu (MET, 86.1.2a) and of Ankhefenkhonsu (RMO, AMM18-g1). The images are courtesy and authorised by the Metropolitan Museum of Art, New York and the Rijksmuseum van Oudheden, Leiden.

have an identical orthogonal projection and can be accurately overlapped[38].

The "layers" allow us to have the first autoptic inspection of the difference between lids with and without colour. When the decoration layer ("layer" 1) is switched off it is possible to better observe some peculiarities and particulars that were indiscernible to the naked eye due to the paint covering. Comparing the two visualisations it is clear that in most cases the objects or some of their elements can appear very different in their geometry and show variability. The faces, for example, are not idealised faces, serially produced with schematic and homogeneous facial features, but all of them present specific traits with different forms, positions and dimensions of the oval, eyes, eyebrows, nose, mouth, ears and earrings (Figure 4).

This huge variability in the forms and geometry, especially compared to the use of paint, regards not only the masks, but also the wigs, the hands and is particularly evident in the rendering of forearms. In painting we only have 3 ways to draw the forearms: arms and forearms fully visible (Type I), partially covered by a large collar (Type II) and fully covered by the collar (Type III)[39]. These three different representations of the forearms were considered a key index for the typology of yellow coffin in terms of a chronological evolution: from oldest to newest[40]. However, geometrically, scholars only considered if arms and forearms were fully modelled or missing[41]. Nevertheless, "layer" 2 shows that there is much greater variability in the rendering of forearms with huge degrees of variation from one coffin to another starting from the full or partial representation of forearms to their orientation. The forearms, in fact, can be fully or partially represented, they can be arranged transversally or in a V-form, they can have merely the elbow rendered or nothing at all, they can have just a squared or rounded lower line, the cross can be fully rendered or not at all and can even be wrong - with the left forearm placed upon the right one (Figure 5).

Moreover, when forearms are represented in decoration, it cannot be automatically predicted that they are also rendered in the geometry. In fact, sometimes the forearms are only painted on a flat surface (i.e. the mummy board of Ankhsenmut, "Museo Egizio" di Firenze, inv. n. 8521, Figure 6a), they are fully rendered in the decoration but are marked by a squared/rounded lower line to create light volume and three-dimensionality, even if the surface is completely flat (i.e. the mummy board of Nesypanebawib, RMO Leiden, AH 1a, Figure 6b). In contrast we can sometimes detect proof of the original forearms in the geometry which are completely concealed under a large painted collar (i.e. the mummy board of Mutemperamun, Museo Egizio, Torino, S. 7715/02, Figure 6c).

So far, the comparison between the Visual appearance and Physical geometry has yielded fascinating and unexpected results especially for those full coffin sets that are formed by an outer coffin, an inner coffin, and a mummy board. In terms of Visual appearance, there are many cases where the figural decoration, the layout of that decoration, as well as the palette and the style used for all the pieces are clearly the same and applied by the "same hand". By switching the colour off we face one of two different situations: either we can see the same strong links also in the Physical geometry or we see that such links existing in the decoration do not exist in the

[38] For the overlapping process Faces Revealed uses Photoshop software

[39] The three typology follows the type identified by Sousa. See Sousa, 2020b

[40] Niwiński, 1988, pp. 68–70; Sousa, 2020b

[41] Niwiński, 1988, pp. 70–82

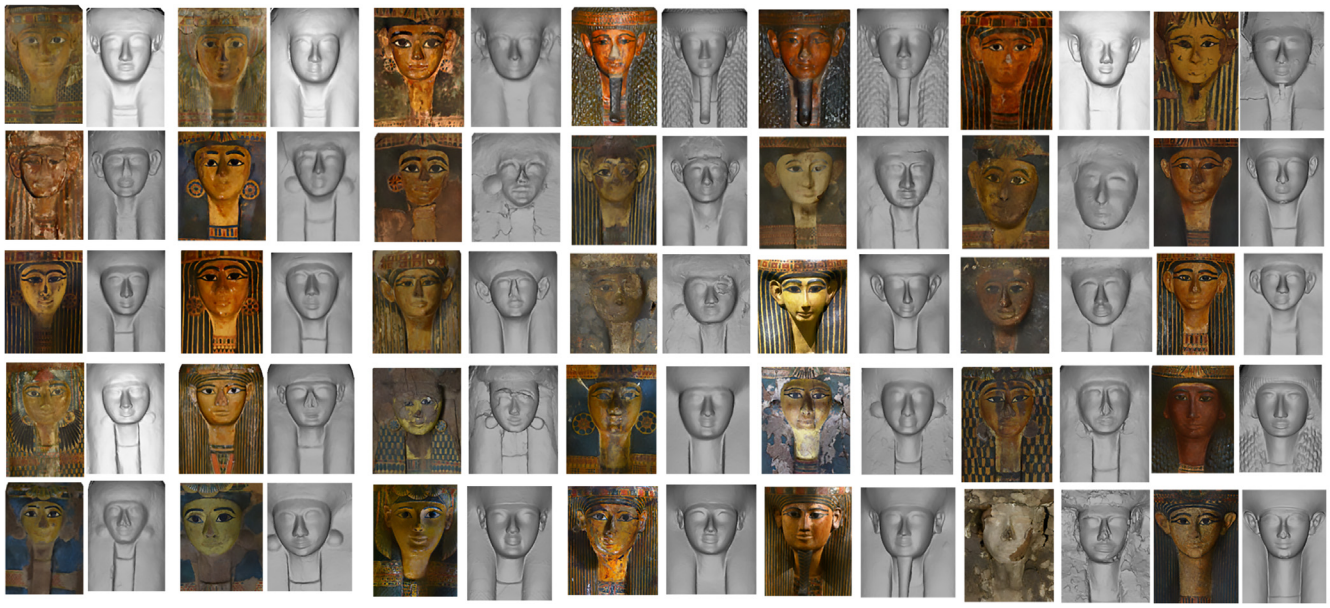


Figure 4. Textured and non textured faces of yellow coffins. The images are courtesy and authorised by the Museums Partner: Museo Archeologico Nazionale di Napoli (MANN); Museo Archeologico Nazionale di Firenze (Direzione Regionale Musei della Toscana); Rijksmuseum van Oudheden, Leiden; Musée du Louvre, Département des Antiquités égyptiennes; Vatican Coffin Project, Governatorato S.C.V. - Direzione dei Musei; Museo Egizio di Torino.

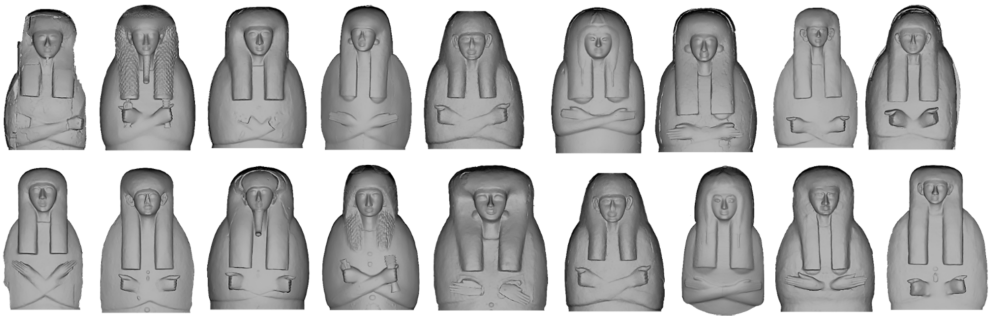


Figure 5. Variability in the rendering of the forearms in non textured orthophotos. The orthophotos are courtesy and authorised by Museo Archeologico Nazionale di Firenze (Direzione Regionale Musei della Toscana); Rijksmuseum van Oudheden, Leiden; Musée du Louvre, Département des Antiquités égyptiennes; Vatican Coffin Project, Governatorato S.C.V. - Direzione dei Musei; Museo Egizio di Torino; National Museum of Egyptian Civilization (NMEC), Cairo; Egyptian Museum, Cairo.



Figure 6. a-c Comparison between textured and non textured orthophotos of three mummy boards. The orthophotos are courtesy and authorised by Museo Archeologico Nazionale di Firenze (Direzione Regionale Musei della Toscana); Rijksmuseum van Oudheden, Leiden; Museo Egizio di Torino.

geometry and that the different pieces forming the same set are actually very different from each other in their Physical geometry. The two possibilities are clearly visible, for example, in the coffin set of Amenhotep in the Musée du Louvre, Paris (Louvre, inv. nos. E 13028, E13030, E 13041) and in the set of Tabakmut in the Metropolitan Museum of Art in New York (MET inv. nos. 25.3.10a, 25.3.11a, 25.3.12).

The set of the *wab*-priest Amenhotep in Louvre was presented by F. Cailliaud to the Bibliothèque Nationale in 1825 and likely comes from Thebes (Figure 7)[42].

The set was dated to the late 21st Dynasty on the basis of the decoration and layout (types IIIb and IIIc), which follows the same conventions in all three pieces. The masks are framed by striped wigs with two or three bands of headbands and a bunch of lotus flowers hanging down from the crown to the head and horizontal end yellow bands. The large collar partially covers the forearms on all the objects and only the elbows are drawn with a lotus flower (type II). The hands, crossed and closed as usual in coffins for male deceased, are attached to the chest. The colour palette is above all dark green and blue on a yellow background and some elements were formed by moulded plaster applied as raised relief. The same uniformity in decoration can also be seen in the geometry, especially on the inner lid and the mummy board: the faces have a short and large forehead with a marked line of the wig which ends on the temples into two short edges in relief. The faces are squared with rounded eyebrows and almond-shaped eyes with a marked shade of circles in the internal part, smiling mouths with thin lips in a particular V-form and protruding and squared chins. The connection in the carving of the faces, the hands and the ears suggest the same craft production brings us to the conclusion that the two pieces were produced to match each other both in craft and in decoration.

The coffin set of Tabakmut in the MET, shows a completely different situation. The set was found in chamber 2 of Theban Tomb n. 60 (TT 60) during the MMA excavations of 1923–24[43] (Figure 8).

The three pieces have a great uniformity in decoration and layout and also in this example the style of the decoration suggests the same "hand", especially in the characteristic and not so common blue/grey paint in the hand hollows on all three objects found – until now - only on one other coffin[44]. On all the pieces the deceased wears a tripartite wig with one or three lines of the crown of justification and a broad collar with falcon heads on the shoulders which cover the forearms. Even if the decoration is the same (type IIIa)[45] and dated to the Middle-Late 21st Dynasty, they are completely different in their Physical geometry. In the Visual appearance, for example, the forearms are only partially painted (type II) but they are also modelled and clearly visible under the collar on all three pieces. In the outer and inner lids, they are simply realised with curved lines arranged transversally, while in the mummy board there is the full rendering of the crossing with the right arm on the left one.

Beyond this macroscopic particularity, another characteristic of the set is that all the masks, ears and hands are very different to one other, and the outer and inner masks have very distinctive facial features (Figure 9).

After the autoptic comparison, the second phase of the methodology is the creation of another two "layers" for the objective analysis on how the decoration is applied on the three-dimensional features. The two layers have been created

[42] Niwiński, 1988, p. 164, n. 329; Rigault-Déon & Niwiński, 2024, pp. 400–463, Cat. 13 a-e. For pictures see on-line Louvre site des collections, https://collections.louvre.fr/en/ark:/53355/cl010028760.

[43] Aston, 2009, p. 201; Niwiński, 1988, p. 160, n. 311; Winlock, 1942, pp. 100–116, pl. 85. For 3D models see Mainieri, 2023e. For pictures see the MET on-line catalog https://www.metmuseum.org/art/collection/search/551105

[44] Mummy board of Nesypanebawib, RMO Leiden, inv. n. AH 1a. Cooney, 2018b, p. 75, n. 6.3; Niwiński, 1988, p. 145, n. 221

[45] Niwiński, 1988, p. 160, n. 311



Figure 7. Textured and non textured orthophotos of the coffin set of Amenhotep (Musée du Louvre, Paris, inv. nos. E 13028, E13030, E 13041). The orthophotos are courtesy and authorised by the Musée du Louvre, Département des Antiquités égyptiennes.



Figure 8. Textured and non textured orthophotos of the coffin set of Tabakmut (MET, inv. nos. 25.3.10a, 25.3.11a and 25.3.12). The orthophotos are courtesy and authorised by the Metropolitan Museum of Art, New York (MET).

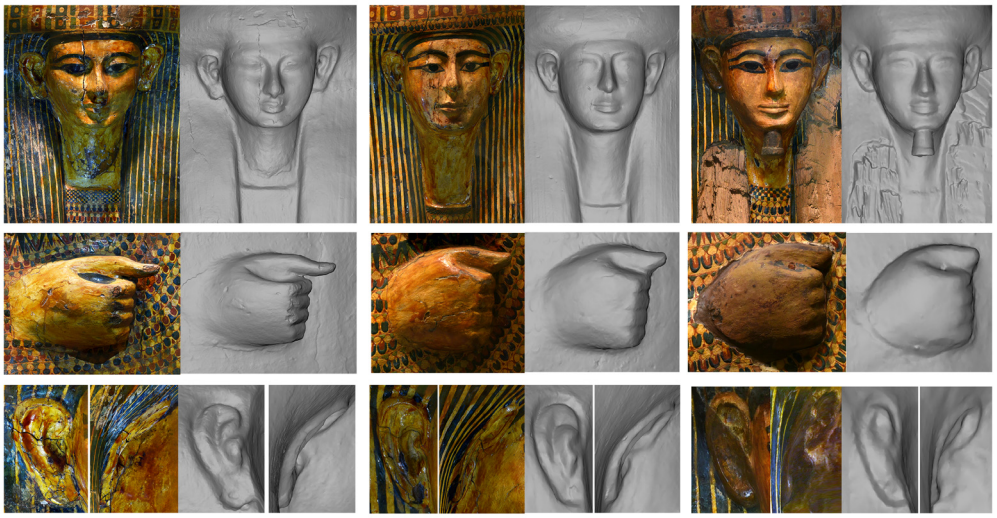


Figure 9. Particular of the faces, hands and ears of the coffins of Tabakmut (MET, inv. nos. 25.3.10a, 25.3.11a and 25.3.12). The orthophotos are courtesy and authorised by the Metropolitan Museum of Art, New York (MET).

through the one open-source paint.net software[46]. One "layer" is dedicated to tracing the decoration (considering only the elements which are objects of the study and not the full decoration – "layer" 3) while the other "layer" to highlight the geometry through points ("layer" 4) have been created[47]. These two "layers" can be overlapped in transparency on the solid model, on the texturised model and also between them, thereby maintaining the same orientation and the same proportions. This image overlapping enables a more precise inspection of objects and tracing the conformity of the two layers giving an insight into how ancient artists applied the coloured features on the three-dimensional masks, analysing any possible corrections that were applied to the geometry through the paint.

[46] To download the software: https://www.getpaint.net/index.html.

[47] For decoration the project uses the line/curve black in colour with the brush size 5, for the geometry red points (paintbrush size 10) and blue lines size 5 t. Both layers are in .tiff format which maintains both high resolution and transparency of the file.

The overlapping of the four "layers" demonstrates that only in 37% of the coffins does the Visual appearance and the Physical geometry match exactly. There was a 13% mismatch on at least three painted features while in 46% they partially match, i.e. less than 3 features. The mismatch can relate to the form of the mouth and/or the thickness and form of the lips, as well as the ears which can be reduced in dimension when painted. Similarly, the mismatch could be seen in the form of the face (both bigger or smaller), in the position of the painted eyebrows and eyes on the mask, in the form of the arms, even if the features that, in percentage terms, do not match are above all the eyes, ears, and mouth/lips.

When we say that the different layers exactly correspond to each other it means that the paint does not transform the original crafted features and that the decoration maintains the same proportions, features and forms realised in the geometry (Figure 10, 1a–c). Comparing the two visualisations, then, we can recognise the object. The same can be observed when there is a partial match, with a modification of less than 3 features. The decoration, in fact, seems to modify only

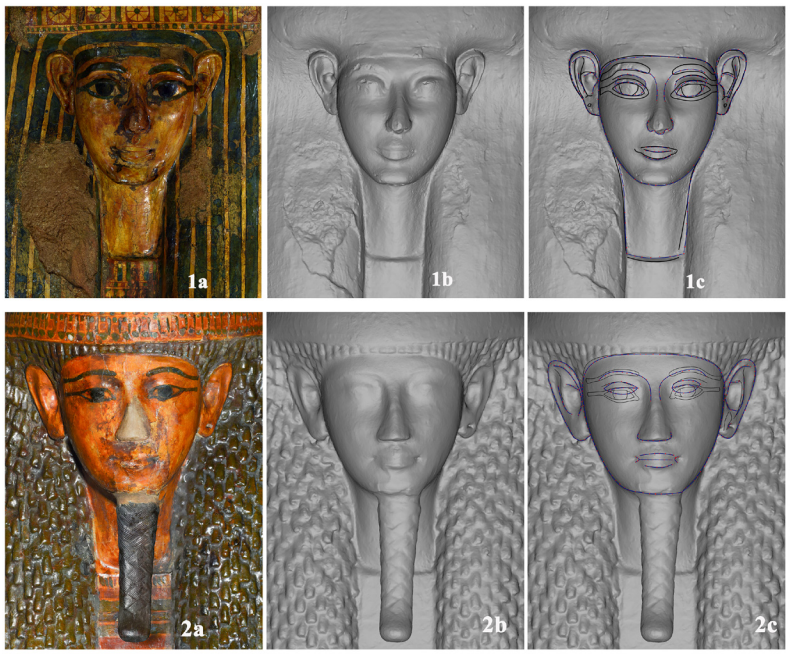


Figure 10. Particular of the matches between the "Layers": Khonsumes (**1a**–**c**) and Butehamon (**2a**–**c**) (Museo Egizio, Torino, Cat. 2238/01 and 2237). The orthophotos are courtesy and authorised by the Museo Egizio, Torino.

a few features linking the discrepancies between layers more to a specific production or to adjustment and correction of errors - such as asymmetry between the two sides of the face - more than a deliberate will to transform the mask (Figure 10, 2a–c).

On the contrary, when we talk about full mismatch in decoration we have a completely different perception of the mask with and without decoration and, in this case, it is clear that colour was used to transform and modify the original crafted features. A very interesting example of changing forms and proportions of the mask through decoration is the outer lid of the Charioteer of the Overseer of the Army, Iotefamun (MET 26.3.1a)[48]. The coffin, discovered in 1920–21 in pit 1016 at the Mentuhotep temple area in Deir el-Bahari[49], was found with an inner coffin (MET 26.3.2a–b)[50] and a mummy board (MET 26.3.3)[51] which are now in the Virginia Museum of Fine Art (VMFA, L.7.47.77)[52].

The outer lid of Iotefamun corresponds to the type IIa and was dated by Niwiński firstly at the early 21st dynasty (1000 BCE ca.)[53] and later to the late Ramesside period (1295–1069 BCE ca.)[54]. The lid represents a male deceased as testified by the closed hands and the uncovered ears (male gender markers). The face is drawn in a red line over the yellow ochre with black hieroglyphic eyes framed by curved eyebrows becoming straight on the side and aligned with the makeup, and with a thin red line traced between the eyes and the eyebrows to define the eyelids. The nose is large with nostrils in red and the mouth is unsmiling, schematic and large with thin lips and circles at the corners. The deceased wears a long tripartite plain blue wig, the ears are uncovered and naturalistic in style with lines and holes on the lobe in red (Figure 11a).

On the geometric point of view the outer lid is rounded in shape with a protruding belly, crossed forearms carved in high relief with the right arm on the left one and close, small and squared hands with stubby thumbs. The wig is rounded with short lappets, but was originally curled. Geometrically, it is clear that the wig was intentionally modified and transformed from a curly to a plain one. The waves, hardly visible to the naked eye, are clearly recognisable in the geometry at the top and the outermost lateral sides. This flattening modification was executed in a rough manner using both a dark colour and a thin layer of plaster. The face is rounded with a high and flat forehead, high cheekbones, full cheeks and an oval chin; the forehead is flat and high but presents a

[48] Aston, 2009, p. 232; Bettum, 2018; Niwiński, 2019; Porter & Moss, 1964, p. 668; Winlock, 1942, pp. 31–46, pl. 80

[49] Winlock, 1942, pp. 34–35, pl. 80

[50] https://www.metmuseum.org/art/collection/search/557209

[51] https://www.metmuseum.org/art/collection/search/557210

[52] Unfortunately, the two objects are not included in the Faces Revealed *corpus*.

[53] Niwiński, 1988, p. 161, n. 314

[54] Niwiński, 2019

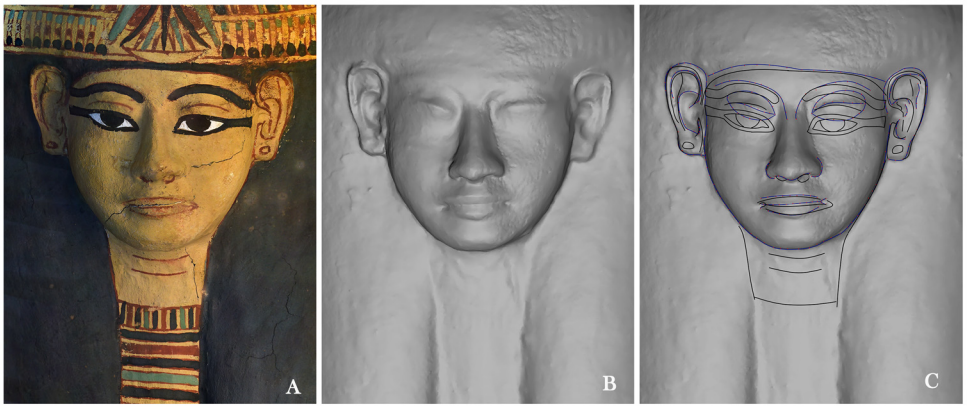


Figure 11. Particular of the matches between the "layers": Iotefamun (MET, inv. n. 26.3.1a). The orthophotos are courtesy and authorised by the Metropolitan Museum of Art, New York (MET).

line in the middle, as a kind of modification; The eyebrows are arched and frame two highly protruding, oblique, and almond-shape eyes located at the level of the root of the nose; the nose is big, narrow at the root and large at the base; the mouth is unsmiling and narrow with thin lips and hollows in the corners; the ears, naturalistic and big with separate lobe, are located in the area between the line of the wig and the base of the nose; the neck is three-dimensionally rendered but small and with any line of separation with the collar (Figure 11b).

Even if it is already clear that the mask looks completely different without paint, overlapping the layers we can analyse in more detail these differences and see how the colour transformed the forms. In addition to the modification of the wig, the proportion and the facial features were clearly modified (Figure 11c):

i. the oval of the face is reduced in the upper part colouring partially the forehead;

ii. the big ears are reduced covering the external part of the pavilion, an element found also in the coffin set of Butehamon[55];

iii. the black eyebrows do not follow the modelled arched form[56] but are drawn in the space between the line of the upper eyelid and the eyebrow;

iv. the eyes start under the bulged three-dimensional eyes and appear painted in the upper part of the cheeks;

v. the red line for the eyelid is in the wrong position, not in the curvature but painted upon the most prominent part of the bulged eye;

vi. a schematic and large mouth that overpasses the width of the nose, with thin and schematic lips, has replaced a narrow mouth.

The high modification of forms on the mask may suggest more the intentional will to change the proportions, the features and perhaps the style of the coffin rather than a simple correction of errors made by the painter during the production process[57]. These elements could suggest a possible reuse of an older coffin, a hypothesis corroborated by the original curly wig which is characteristic of older periods and by the fact that the style of the inner lid coffin and the mummy board of the same set are typologically completely different.

The morphometric approach. Markers, variables and types

The second part of the Faces Revealed Methodology represents the most challenging task of the project: to understand if different objects can be connected based on the way specific features have been rendered. The main objective is to identify possible common styles and trademarks of production.

This part of the work draws inspiration from the Morellian Method based on the concept that 'incidental details of the way a particular artist portrays ears and hands, might be used to attribute unsigned paintings or sculptures to known artists'[58]. Following this approach, repeated patterns could correspond to habitual techniques that could be associated with a workshop or individual artist. In the decoration layer, we know that this is possible as evidenced in different studies[59]. For example, this is clearly visible on two yellow coffins in the Museo Archeologico Nazionale di Napoli

[55] Mainieri *et al.*, 2022

[56] The black or blue eyebrows were normally drawn up the sculpted/modelled line or across it.

[57] Use of colour "to mask the poor work of the sculptors" is well known in the tombs. See for example the tomb of Mereruka, Pieke, 2011

[58] Hartwig, 2015

[59] Johnston, 2022; Niwiński, 1988

(MANN) which are linked by specific trademarks to each other and to other two yellow coffins, suggesting a common production[60].

As we explained, there is a huge variability in geometry, greater than in decoration, so the possibilities are numerous. Moreover, faces and features may be produced with a large amount of plaster or be sculpted on wood; the availability of resources, the type of materials, as well as the abilities of a single artist and the resources of the clientele are all elements that can have a significant impact on the final result and consequently affect this kind of study. Even if we have to consider all these elements and pay attention, it is anyway possible to link objects to each other based on specific features, as inner lid and mummy board of Amenhotep testifies (see *supra*).

But is it possible to identify markers and link coffins which are not part of the same set?

To try to answer to this question, the coffins were digitally "dissected", taking into account fixed variables, equal both in Visual appearance and Physical geometry. Seven variables were identified for Visual appearance and nine for Physical geometry[61]. Once isolated, each variable was analysed following a morphometric approach, starting from the forms, with the measurements, to better classify shapes and to understand the proportions of each part related to the general dimension of the object.

Measurements were taken by overlapping "layer" 2 (Physical geometry) with "layer" 4 (the "layer" that highlights geometry through points). Both were loaded and scaled into the AutoCAD software. Each object was entered onto a grid system that allows all linear measurements of the object to be controlled. The main horizontal and vertical lines of the grid intersect at the point of the nose to divide the face into approximate quarters that vary according to the face. The vertical and horizontal distances represent the variables related to the face with its four main components: eyes, ears, nose and mouth (Figure 12)[62]. Each variable has specific markers identified through Latin or Greek letters and/or numbers and colours, a choice that makes it easy to identify the feature and the side (upper, right or left) to which it relates.

This grid system allows to control of all the linear measurements of the object. The grid dedicated to the face, for example, allows measurement of the main distances: the distance between the midpoint of the hairline and the lowest point of the chin (**A–C**) and the distance between the endpoints of the left and right cheeks (**D–E**). Other horizontal lines further divide the face into 3 horizontal parts: the forehead area (**A–Ø**); the eye and nose area (**Ø–5**); and the mouth and chin area (**5–C**). These measurements help to classify the forms and group faces into specific categories. Facial features are measured following the same principle: for each eye, both the distance between the outer and inner corner of the eye slit (**eR2–eR4, eL2–eL4**), their maximum height (**eR1–eR3, eL1–eL3**) and their distance (**eR2– eL2**) are considered; for the nose, the maximum height from the root to the base of the nasal septum (**0–5**) and the narrowest (**1–2**) and largest (**3–4**) parts; for the mouth/lips the maximum height (**α–γ**) and the width (**δ–ε**); for the ears the distance between the outer point of the ears, in height (**hR1–hR2, hL1–hL2**) and width (**hR2–hR3, hL2–hL3**). For the ears and earrings the grid system also helps to reference their position related to the face.

By combining drawings, points and considering the measurements, the main variables were categorised and then, a closed vocabulary with short codes corresponding to specific types was created[63] (Figure 13).

This step was fundamental because allowed the construction of a Compare Spreadsheet with all the coffins and their categorised variables. The Compare Spreadsheet identifies which and how many common features the coffins share - considering both visualisations - highlighted in different coloured boxes (Figure 14).

Using this approach it is clear, for example, that the inner lid (E13030) and the mummy board (E13041) of Amenhotep in the Louvre (in blue) have the same production, both in decoration and geometry, different from the outer lid which shares only Visual appearance and not Physical geometry features with the other two pieces, or that the outer coffin of Butehamon in Torino (Cat. 2236)(in yellow) represents a different production both in decoration and morphology with respect to its inner lid and mummy board (Cat. 2237/01-03) which are, instead, identical on both visualisations (Figure 14 and Figure 15)[64].

Even if these connections and differences are visible also with the autoptic observation (see *supra* § 2.3), this categorisation allows a reliable and consistent inspection of all the variables which the comparison objective, further it enlarges the comparison itself to all the *corpus* because it enables a contemporary comparison of the variables of all the coffins, highlighting the common ones and then making it

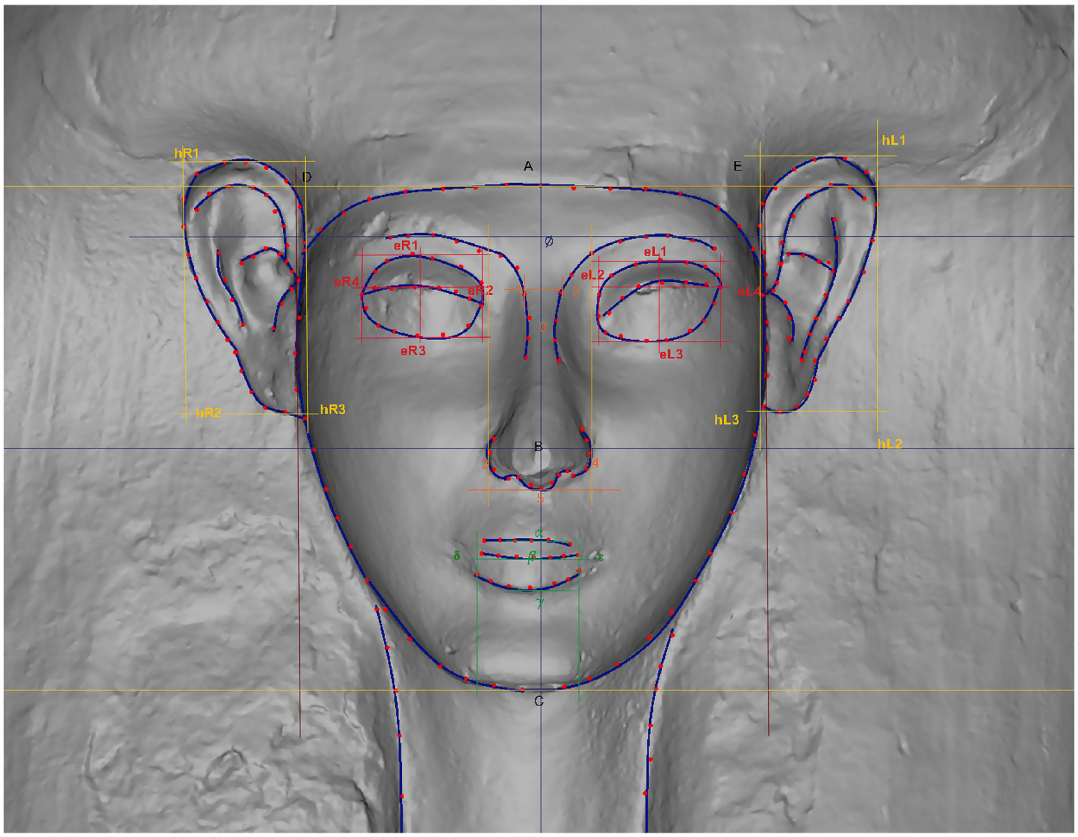
[60] Mainieri, 2023b

[61] The common features are Wig, Breasts, Eyebrows, Eyes, Mouth, Ears/Earrings, Forearms and Hands. The Face, Nose and Shape are variables considered only in Physical geometry.

[62] Unlike the initial stage of the project, the wig and hands are also included in the variables.

[63] For each sector with the nickname **Va** are indicated variables linked to the Visual appearance, with **Pg**, those related to Physical geometry. The next letters represent the first letter(s) or acronym of each part/variable (**W**= Wig; **B**=Breasts; **Eb**=Eyebrows; **Ey**= Eyes etc.). Number is the main category based mainly on shape and geometry. The main type can be divided into two or more subtypes, denoted by Greek letters (**α, β, γ**...), identified for specific characteristic such as their position, size or for the presence/ absence of specific features (i.e. the hole in the ear lobes)

[64] Mainieri *et al.*, 2022; Mainieri, 2023c; Mainieri, 2023d



VARIABLE	MARKERS			
		TOP	RIGHT	LEFT
WIG	height	G-M		
		F-A (cranium)		
	width	G-H		
		M1-N (lappet)		
FACE	height	A-C		
	width	D-E		
1/3 FACE	height	A-Ø		
2/3 FACE	height	Ø-5		
3/3 FACE	height	5-C		
EYES	height		eR1-eR3	eL1-eL3
	width		eR2-eR4	eL2-eL4
	distance	eR2-eL2		
NOSE	height	0-5		
	width	1-2		
		3-4		
SPACE NOSE-MOUTH	height	5-β		
MOUTH	height	α-γ		
	width	δ-ε		
SPACE MOUTH-CHIN	height	β-C		
EARS	height		hR1-hR2	hL1-hL2
	width		hR2-hR3	hL2- hL3
HANDS	height		zR1-zR2	zL1-zL2
	width		zR3-zR3	zL2-zL3
	distance	zL3-zR3		

Figure 12. Variables and Markers for measurements. The orthophoto is courtesy and authorised by the Museo Egizio, Torino.

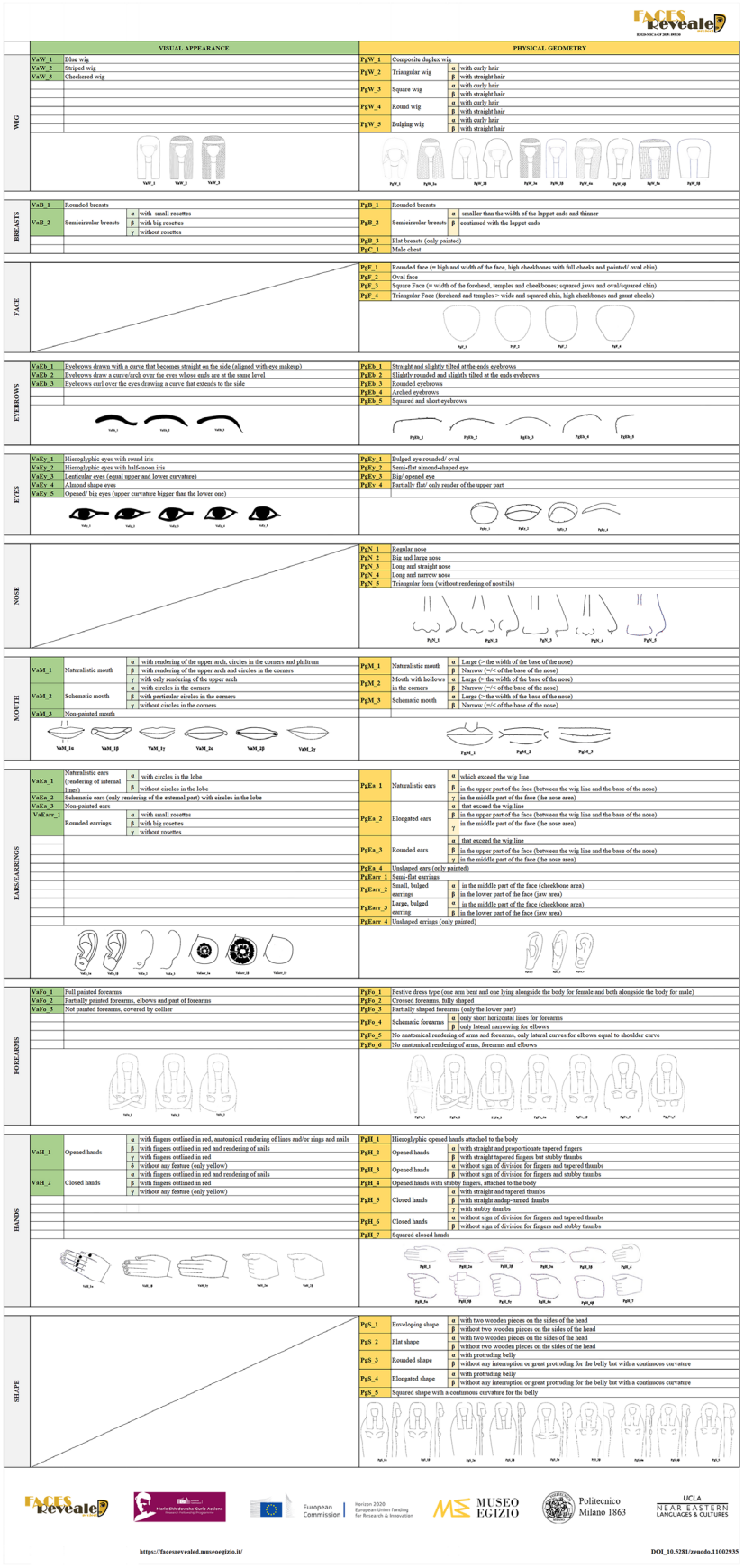


Figure 13. Vocabulary and types (© Faces Revealed Project).

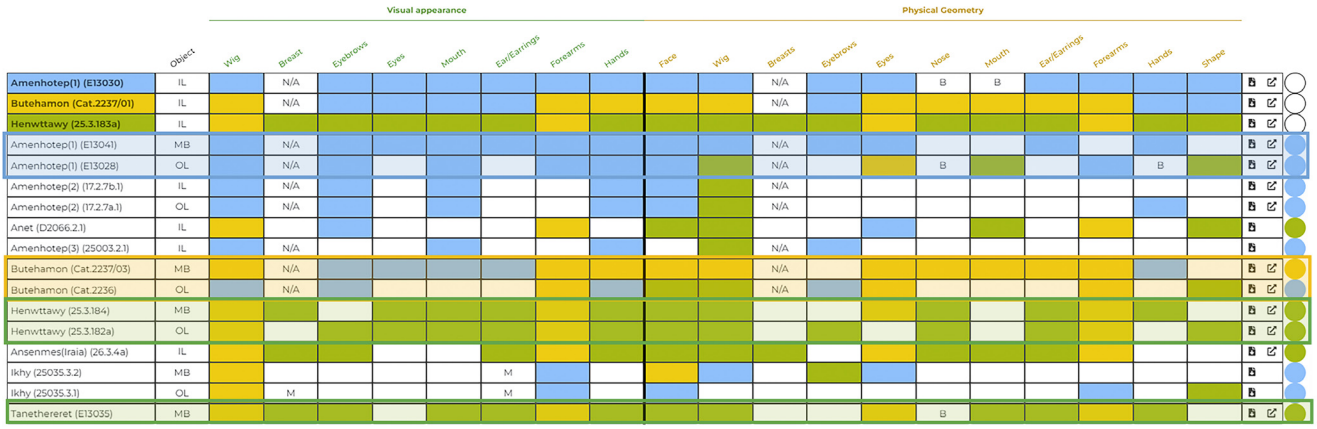


Figure 14. The Compare spreadsheet that highlights the common features in the coffins (© Faces Revealed Project).

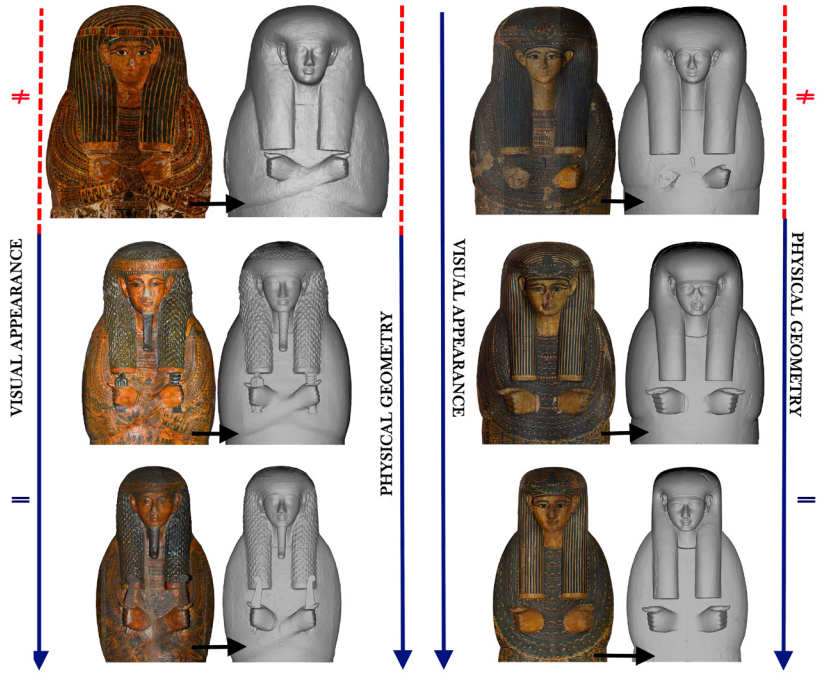


Figure 15. Differences and affinities in Visual appearance and Physical geometry within the coffin set of Butehamon (left) and Amenhotep (right). The orthophotos are courtesy and authorised by the Museo Egizio, Torino and the Musée du Louvre, Département des Antiquités Égyptiennes.

easy to identify links and differences[65]. Among the results obtained by this method, for example, is the "discovery" of the link between the inner lid and the mummy board of Henwttawy (MET, 25.3.183a, 25.3.184), with the three pieces forming the set of Tanethereret (Louvre, E 13027, E 13034, E 13035). The way of rendering the features and the human body is the same in both Visual appearance and Physical geometry. We have, in fact, the same kind of decoration and the same "style" in the rendering of forms, evident especially in the two mummy boards (Figure 16).

The precise connection between these objects enables one to ascribe the sets to the same production style, and speculate

[65] The Compare spreadsheet is open to use on the webpage of the project with the possibility to download the results of the research in a reusable .xls file https://facesrevealed.museoegizio.it/



Figure 16. Connections between the mummy boards of Henwttawy (half right) and of Tanethereret (half left). The orthophotoa are courtesy and authorised by the Metropolitan Museum of Art, New York (MET) and the Musée du Louvre, Département des Antiquités égyptiennes.

on a possible common "workshop"/ artist, a contemporary time of production or perhaps the existence of a "reference model" for the production of coffins in a specific place or time[66]. These thoughts originate from the presence of a fixed type of Variables – trademarks (?)[67] – also on other coffin lids, all female, ascribed to the Niwinski macro-type II[68], and dated between the end of the 20th and the early 21st dynasty[69]. Further analyses on the group are in progress, but it is clear that the Compare Spreadsheet represents an important step in the research and that an in depth analysis of features discloses abundant information about the production of coffins.

Conclusion

The paper presents the complete developed and applied methodology of the Faces Revealed Project and introduces to the scientific community an important use of 3D models applied to the Egyptological field in an ongoing research activity[70].

The Faces Revealed Project is a new line of research in the Humanities where Digital Technologies and 3D models are "key tools" for research, adding new information and elements to the "traditional" research on polychrome three-dimensional objects. 3D models of yellow coffins allow us to analyse in detail the geometry and form and create orthophotos and different "layers", enabling a much more precise analysis of the correspondence between decoration and geometry. The presence or absence of connection between the different "layers" offers an indication of the time of production of individual pieces, such as if they were produced together and, above all, whether or not they are contextual both in terms of their craft and paint, suggesting a different place of production, a possible low quality of the committee and/or "workshop" or constituting an example of reuse with different pieces being remade to match each other through decoration.

The second part of the Faces Revealed Methodology represents the most challenging task of the project: understand if the different ways of rendering shapes, ears, breasts, and mouths may be considered trademarks able to connect different coffins and place them in a specific place ("workshop") and time (chronology) of production. To identify these connections the coffins have been "dissected" and each feature forming the human body analysed and categorised to facilitate the research. As the examples of the coffin sets of Henwttawy and Tanethereret show, the most important result of this part of the methodology is the possibility to group objects and identify types not only based on Visual appearance but also on their Physical geometry giving more information about the production of yellow coffins and reconstructing a part of Ancient Egyptian history still too little known.

[66] Mainieri, forthcoming

[67] The markers in geometry are: small earrings located at the middle of the face or slightly below; the breasts, smaller than the width of the lappets or very small and rounded and the well rendered hieroglyphic hands, flat and attached to the body.

[68] Niwiński, 1988, pp. 71–76

[69] Ansenmes (Iraia), MET 26.3.4a; Anet, MuseiVaticani D 2066.2.1; Tanetimen, Musée du Louvre N 2562; Tabakenkhonsu Museo Egizio, Torino Cat. 2226.

[70] The results of the findings will be presented in other articles and the future monograph.

Ethics and consent

Ethics and consent were not required.

Data availability

Underlying data

The Faces Revealed Project is accessible at the public page https://facesrevealed.museoegizio.it/. The raw and generated data and metadata are and will be stored in a Zenodo repository at the link (https://zenodo.org/communities/facesrevealedprojectmsca895130?q=&l=list&p=1&s=10&sort=newest and below). Full or limited access is regulated according to individual museums' copyright restrictions.

Zenodo: 3D Models of the yellow coffins in the Museo Egizio, Torino (Italy) (1.0). https://doi.org/10.5281/zenodo.10589491 (Mainieri, 2024a). This project contains the following underlying data:

- 3D Models of yellow coffin lids in the Museo Egizio, Torino

Zenodo: 3D Model of the Mummy board of Butehamon, Museo Egizio, Torino (Inv. n. Cat. 2237/03) (Version 2). https://doi.org/10.5281/zenodo.10722083 (Mainieri, 2023c).

- 3D model of the mummy board of the Royal Scribe of the Necropolis Butehamon (Museo Egizio, Torino, Cat. 2237/03).

Zenodo: 3D Model of the Inner lid of Butehamon, Museo Egizio, Torino (Inv. n. Cat. 2237/01) (Version 2). https://doi.org/10.5281/zenodo.10722825 (Mainieri, 2023d).

- 3D model of the yellow coffin's inner lid of the Royal Scribe of the Necropolis Butehamon (Museo Egizio, Torino, Cat. 2237/01).

Zenodo: 3D Models of the yellow coffins in the Rijksmuseum van Oudheden, Leiden. https://doi.org/10.5281/zenodo.10992877 (Mainieri, 2024b).

- 3D Models of yellow coffin lids in the Rijksmuseum van Oudheden, Leiden

Zenodo: 3D Models of yellow coffins in the Musée du Louvre. https://doi.org/10.5281/zenodo.11063613 (Mainieri, 2024c).

- 3D Models of yellow coffin lids in the Musée du Louvre

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).

The following data cannot be made publicly available due to individual museums' copyright restrictions. To have access to the data please contact the author.

Mainieri (2023e). 3D Models of the coffin set of Tabakmut, Metropolitan Museum of Art, New York (Version 2) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.10723049

Mainieri (2024d). 3D Models of yellow coffin lids in the Museo Archeologico Nazionale di Napoli (MANN) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.11002992

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Mainieri (2024g). 3D Model of the yellow coffin of Padiamon in the National Museum of Egyptian Civilization (NMEC) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.11003100

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All researchers, scholars and institutions mentioned in this section and the footnotes are Partner of the Project and have given their permission for their names and affiliations to be included in this publication.

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Version 1

Reviewer Report 06 November 2024

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✔ **Caroline Arbuckle MacLeod**
University of Saskatchewan, St Thomas More College, Saskatchewan, Canada

The Faces Revealed Project is a novel approach to the study of coffins, and represents a significant data set for Egyptologists working on funerary materials. As the author rightly notes, the Egyptological focus on coffin decoration has added considerably to our understanding of Egyptian religion, but these funerary containers have the potential to reveal much more about ancient Egyptian society, especially related to the actions of craftspeople. A particular strength of the discussion is the comparison of the visual appearance of the facial features of coffins compared to their physical geometry. The author lays out their methods for this approach carefully, demonstrating how photogrammetry can be used to create a visual representation of the coffin's shape, free of distracting painted decoration. I think this is an excellent means of demonstrating the extent to which the painting phase of coffin creation could be used to modify the crafted face.

The second part of the article, related to tracking hands, also has some interesting conclusions. I think the author's detailed classification guide for different features in both shape and decoration is also very useful. I found the classification system quite complicated, and was grateful for the figures that helped to illustrate and summarize differences and affinities in visual appearance and physical geometry within specific coffin sets.

Given that this is the first step for this project, I think it adds considerably to our knowledge. Beyond tracking artists' hands, it would be interesting to know what additional research questions this data had inspired for the author. For instance, the author notes that details were often constructed from plaster. It would be interesting to know how many of the faces with well-aligned decoration also had considerable plaster remodeling, and/or whether the heavily repainted models lack plaster modifications. This might help indicate the types of remodeling being considered and which types of craftspeople needed to be involved.

In total, I think this is a very useful and interesting project, and a great new means of assessing craftsmanship in Egyptian coffins. I think it opens up very exciting new approaches for research.

Is the rationale for developing the new method (or application) clearly explained?

Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full access and reuse by other researchers?
Yes

Are the conclusions about the method and its performance adequately supported?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Egyptology, Archaeology, Wood Science, Egyptian Coffins

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 10 October 2024

https://doi.org/10.21956/openreseurope.18827.r44319

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Willeke Wendrich
[1] Politecnico di Torino, Turin, Piedmont, Italy
[2] Near Eastern Languages and Cultures, University of California Los Angeles College of Letters and Science (Ringgold ID: 118546), Los Angeles, California, USA

The Faces Revealed Project provides a well-developed method to research the practices, as well as the communities of practice involved in the production of 21st Dynasty wooden coffins, by creating detailed three-dimensional models and comparing the wooden sub-structure with the painted appearance of the coffins. In the last decade research into coffins from this period has shown that many of the 21st dynasty coffins were a re-use of older models, which were sometimes recarved, but mostly repainted to fit the appearance that was required for the up-to-date style of this period. Hairstyles, and especially the shape of hands, breasts and the ratio of faces (location and shape of eye-brows, eyes, nose and mouth) were adapted by repainting and thus hiding the original features that can clearly be seen when the paint layer is “stripped away” from the three-dimensional model. The Faces Revealed project for the first time embarked on this research in a

most thorough and systematic way. High quality three-dimensional models and a rigorous research protocol has provided a base line of important information that will be the standard for decades to come. It has replaced the purely stylistic analysis that has been the standard so far.
The results of the research show that coffin sets for the same person (often consisting of mummy board, inner coffin, outer coffin) were made from various pieces that originally did not belong together, but were given a unified appearance as a "set" through overpainting. The project also enables a second research avenue that addresses the characteristics of the various ateliers or even of individual artists/artisans. The approach to this line of research is careful and well-balanced.
The excellent illustrations in the article display an effective use of supporting, or perhaps even making the argument.
The project makes the full data in the form of the individual three-dimensional models available for further research.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full access and reuse by other researchers?
Yes

Are the conclusions about the method and its performance adequately supported?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Egyptology, archaeology, history of architecture, digital humanities

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 09 October 2024

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Mona Hess
University of Bamberg, Bamberg, Germany

This article summarises the efforts to create this new corpus of a unique typology of Egyptian yellow coffins, distributed among collections around the world. Furthermore, the successful "Faces Revealed" Project has been published in an exemplary manner, including the publication of all acquired data on Zenodo, a web-based viewer-friendly publication on Sketchfab, accompanied by an informative website showing how the project has been disseminated to the public and the scientific community.
The method used is based on 3D imaging methods with metric control and according to geomatics procedures for best image acquisition and optimised processing, taking into account the functionality for this research (calibrated targets, error margin, resolution, lighting, etc.). 3D imaging methods are now well established in cultural heritage and archaeology, as is colour or greyscale visualisation, but the proposed method of investigation, of superimposing geometries and colours for autoptic and morphometric inspection of these objects in order to gain new knowledge, is a contribution to applied science. Systematic comparisons can be facilitated and visualised with the aid of property tables. It represents a transferable, reproducible methodology that could be applied to other typologies of three-dimensional objects.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full access and reuse by other researchers?
Yes

Are the conclusions about the method and its performance adequately supported?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: 3D imaging, geomatics, cultural heritage, digital heritage

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 30 September 2024

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Andrea D'Andrea
Università degli Studi di NAPOLI "L'Orientale", Naples, Italy

The paper examines the use of photogrammetry for the restitution of a collection of Egyptian painted sarcophagi. After listing and describing the category of artefacts, the author proposes a methodology for the acquisition and processing of this heterogeneous corpus of sarcophagi held in different museums. The author's goal is to examine the geometry of the sarcophagus, which is often not recognizable due to the pictorial decoration. A morphometric approach can contribute to a more correct identification of chronology and places of production. The article is a good example of how 3-D replicas can be used for scientific and not just communication purposes. The idea is very original and well carried out by the author. The contribution can be fully accepted.
I would recommend that all the tables and figures in the text, which often hinder easier reading, be moved to an appendix. Figure 13 is illegible. The article as presented is complete. However, I would suggest in the introduction to also describe the construction techniques and not only the history of the studies.

Is the rationale for developing the new method (or application) clearly explained?
Yes

Is the description of the method technically sound?
Yes

Are sufficient details provided to allow replication of the method development and its use by others?
Yes

If any results are presented, are all the source data underlying the results available to ensure full access and reuse by other researchers?
Yes

Are the conclusions about the method and its performance adequately supported?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Archaeology, 3D data-acquisition, 3D processing

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.