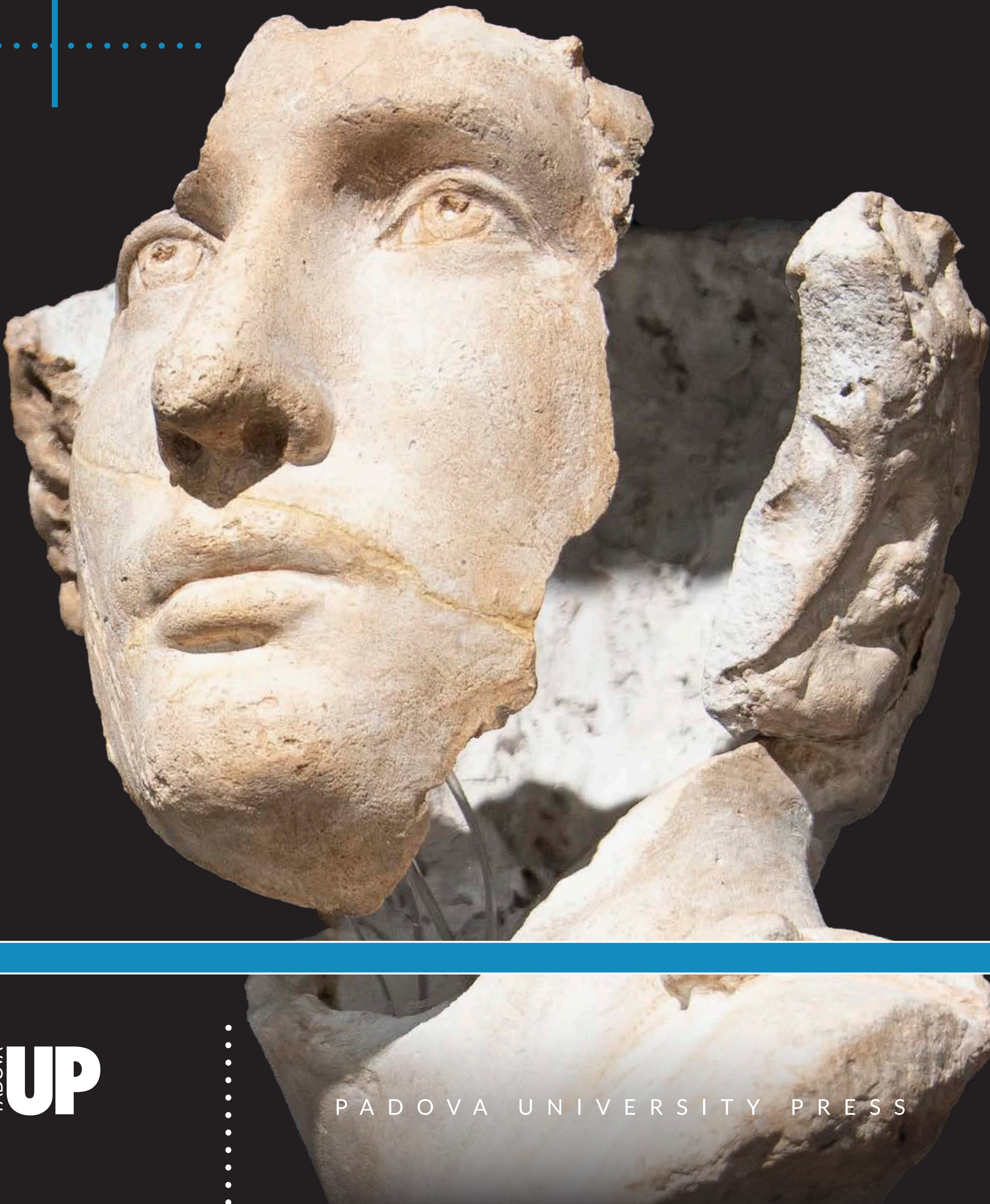
ANTENOR QUADERNI 52

BEYOND FORGERY

COLLECTING, AUTHENTICATION AND PROTECTION OF CULTURAL HERITAGE



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Università degli Studi di Padova
Dipartimento dei Beni Culturali: Archeologia, Storia dell'Arte, del Cinema e della Musica
Piazza Capitaniato, 7 – 35139 Padova

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Università degli Studi di Padova
via 8 febbraio 1848, 2 – 35122 Padova
tel. 049 8273748, fax 049 8273095
e-mail: ordini.padovauniversitypress@unipd.it
www.padovauniversitypress.it

In copertina: *Lucio Vero*, gesso cavo, sec. XVI, collezione Mantova Benavides, MB151. Museo di Scienze Archeologiche e d'Arte dell'Università di Padova (foto di Federico Milanesi, Centro di Ateneo per i Musei - CAM)

UNIVERSITÀ DEGLI STUDI DI PADOVA
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Edited by
Monica Salvadori, Elisa Bernard, Luca Zamparo, Monica Baggio

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Structuring Light for De-Structuring Fake Ceramic Artefacts: the Case Study of a Kylix from the Marchetti Collection

*Giuseppe Salemi, Emanuela Faresin, Luca Zamparo**

Abstract

This article presents a multidisciplinary approach that integrates traditional archaeological methods of investigation with new high-resolution and photorealistic 3D scanning techniques to study the great patrimony of Greek and South Italian vases belonging to various museum collections in the Veneto region. The goal is to create a digital system to be used as a database that contains all the available information about the objects: a 3D archive for the management and cataloguing of the vases and their virtual use and enjoyment in museums.

Keywords: 3D high-resolution models; structured light system; Reflectance Transformation Imaging; mobile virtual light; ceramic artefacts.

Introduction

Digital media are increasingly incorporated in museum exhibitions, and many heritage institutions are now undertaking 3D digitisation of their collections[1]. Digital 3D models of cultural artefacts are used along with traditional activities to document museum objects, heritage sites and archaeological finds, study cultural material without physical access, simulate real-world scenarios, and test restoration and hypothetical reconstructions[2]. Indeed, 3D scanning technology has evolved considerably in the last few years regarding hardware devices and algorithms for processing the raw data produced by the scanning tools[3]. 3D scanning devices are usually based on optical technology and use the triangulation approach (laser or structured light) or the time of flight approach (for large-scale objects).

Modern 3D graphics technologies allow us to acquire accurate digital models of real objects. Such 3D models are the starting point for many applications based on visual representation, ranging from the passive (video, animations, images) to the more interactive and immersive ones (interactive navigation, immersive VR/AR systems). Furthermore, they allow fast, contactless, and remote geometrical and morphometric analyses with a micrometer accuracy (10 – 40 μm)[4].

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* Giuseppe Salemi wrote the "*Introduction*" of this chapter, Emanuela Faresin wrote the paragraphs "*Methods: Acquisition*" and "*Results: Lighting for de-structuring (Post processing)*" while Luca Zamparo wrote the parts of the text concerning "*Material: the Marchetti Collection and a kylix in the style of Gnathia*", "*Discussion: a non-authentic vase*" and "*Conclusions: a multidisciplinary approach for archaeological authentication*".

[1] Younan, Treadaway 2015.

[2] Newell, Lythberg, Salmond 2012, p. 291.

[3] Bernardini, Rushmeier 2002.

[4] Zamparo, Faresin 2018.

The study presented here intends to unite digital analytical methodologies with purely archaeological knowledge and investigation techniques by presenting a case study offered precisely by the union of intentions between different disciplines.

This study is a step into the multi-year research project "MemO – *The Memory of the Objects. A multidisciplinary approach for the study, digitalisation and value-enhancement of Greek and South-Italian pottery in Veneto*". The provinces of Padua and Rovigo stand out for their rich heritage of Greek and South Italian pottery, which has been present in private collections since the end of the sixteenth century and has then converged in many museums of the Veneto Region. The topic of fakes, together with the topic of copies, authenticity, originality, and reproducibility of the artefacts, are essential for studying the history of artistic practice and its reception and the history of art and the history of art collecting. The MemO project, born from the awareness of the social and cultural role played by Greek pottery, will enhance the artefacts present in the public collections of Padua and Rovigo areas through a multidisciplinary approach involving archaeologists, engineers, psychologists, jurists, geologists, and museum professionals.

Material: the Marchetti Collection and a *Kylix* in the Style of Gnathia

Since the eighteenth century, the University of Padua has received various collections of objects that now form part of the University's cultural and museum heritage[5]. In particular, since the beginning of the last century, the archaeological collections have been housed in the Museo di Scienze Archeologiche e d'Arte in Palazzo Liviano, which was strongly supported by the Rector Professor Carlo Anti and designed by the architect Gio Ponti. The collections preserved in the Museum present a heterogeneous and significant material in terms of type and form, so much so that they have focused on numerous research and valorisation programmes undertaken over time by the University.

"I decree that upon my death the entire collection of Italiote, Etruscan and South-Italian antiquities shall go to the University of Padua[6]", so wrote Bruno Marchetti (17 June 1941 - 19 November 2014), a prominent regional politician and new promoter of research into Greek and South Italian pottery at Padua University.

An emblematic figure, Bruno Marchetti, unfortunately, left no documentation of his collection, and what we can reconstruct today is mainly due to the information provided by his heirs and closest acquaintances.

We learn that Marchetti, heir to an essential family of Castelfranco Veneto (Treviso, Italy), had developed from a young age an incessant interest in discovery, which manifested itself above all in his passion for travel: his first solo itinerary was at the age of 18, at the end of his classical studies before embarking on his university commitments (in 1959), with a cruise to discover Egypt, a place where he would return several times during his long life.

He graduated brilliantly in Law and was soon qualified to practice, although he never did. When he was only 34 years old, he joined the Regional Council of the Veneto Region in the second legislature (Giunta Tomelleri, 1975-1980), which he presided over as President also during his second term of office (third legislature, Giunta Bernini, 1980-1985), as an exponent of the "Lombardian Left" of the Italian Socialist Party. In that capacity, thanks to his deep love for art, history, and archaeology, he promoted the exhibition *L'oro degli Sciti* (The Scythians' gold), held in Venice in 1977 under the patronage of the Veneto Region.

In the same years, he was one of the foremost exponents of the Association for Cultural Relations with the Soviet Union (now the Italy-Russia Association), which allowed him to make numerous trips to different states of the Federation, as well as serving as an advisor, on behalf of the Ministry of Foreign Affairs, to the Italian Commission for UNESCO and as a member of the Executive Council of the Venice Biennale.

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5 Menegazzi 2008.

6 Bruno Marchetti's holographic will (copy at the University of Padua).

Fig. 1 – University of Padua, Marchetti Collection 162, *kylix* in the style of Gnathia. Photo by Luca Zamparo.

Returning to his political career, the true driving force of his entire life, in 1985, Marchetti was elected to the Municipal Council of Castelfranco Veneto, which he left in 1990, to then chair it between 1996 and 1999 as First Citizen.

Retiring from political life at the end of the 1990s, Marchetti devoted himself to his great passions. His closest acquaintances describe a profoundly cultured, interested, and curious man who saw no limits to his desire for knowledge. During these years, his already rich library saw a considerable increase in volume, his travels became more and more frequent, as did his contacts with important museums and private foundations in the United States of America and Russia (among them, the Hermitage State Museum in St. Petersburg).

At the same time, his interests ranged from archaeology to crib art, from photography to cinema (his collection of oriental films numbered some 30,000 works), as can be seen from his holographic will, which reveals his possession of "Chinese and pre-Columbian antiquities, as well as Greek, Roman and Arab coins", "a Roman head of a bearded man", "a medieval warrior's head" and several "Russian icons".

After the death of Bruno Marchetti, the family decided to contact the University of Padua: the presence of 356 objects of presumed archaeological nature was verified.

The Superintendence, a local structure of the Ministry of Culture, thus agreed to transfer ownership of the property from the Marchetti family to the University of Padua, an autonomous public body subject to art. 10 co. 1 of Legislative Decree 42/2004, which with the resolution of the University Board of 16 November 2015 (no. 603) accepted the donation and transferred the rights of study and enhancement to the Department of Cultural Heritage. Finally, in December 2015, the entire Marchetti Collection was transferred to the Archaeology Laboratories, where it is still studied and preserved.

As far as the materials in the Collection are concerned, it is worth noting that an initial autopsy of the material revealed a considerable number of problematic pieces, whose authenticity is currently being verified.

The study began with the Attic and South Italian productions, but it should be extended to the entire collection, which has different materials, ranging from statues, bronzes, terracotta. The most consistent nucleus of the material relates to Greek ceramic production, with 108 artefacts, including artefacts from Corinthian production (27), black figures (33) and red figures (30). In particular, the shapes of both Attic black-figure and red-figure ceramics are generally of medium and small size: *kylikes*, *lekythoi*, small *hydriai* and *balsamari* shaped like animal heads. There are 32 vases of Italiote production, mainly from Apula and Gnathia, which are characterised by a great variety of shapes; a large group of ceramics, on the other hand, is attributable to Italiote geometric production (20 examples)[7].

Within these productions, the core of ceramics defined as from Gnathia stands out. The conventional term "Gnathia pottery" or "Gnathia-style pottery" refers to black-glazed production on which overpainting in one or more colours (usually white, yellow and red) was applied before firing, sometimes accompanied by the use of graffiti. Originating in Apulia – presumably in Taranto – around the middle of the fourth century BC, this pottery was exported and imitated in other Magna

[7] Salvadori *et alii* 2018; Salvadori 2019; Salvadori *et alii* 2020.

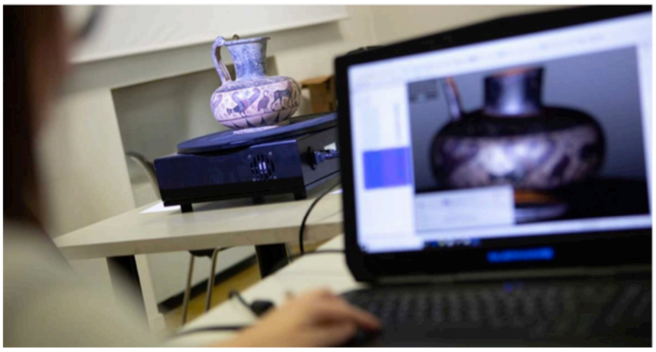

Fig. 2 – Operational image on artefacts from the Marchetti Collection: a structured-light 3D scanning was used to issue a geometric model of micrometric resolution in all its parts; the object was measured with 10 µm accuracy, using an automatic turntable connected to the acquisition software. Photo by Luca Zamparo.

Graecia, Sicily, Lazio, Etruria, central and north-eastern Italy and, finally, in various sites throughout the Mediterranean basin[8]. The traditional name, in fact, immediately calls to mind a precise style, the main characteristics of which are visible above all in the first phase of production[9]: the miniaturistic treatment, the lightness of touch, the tendency to isolate the figure against the black background, the realistic and often caricatured expression of the characters, the search for perspective in the rare landscape motifs, the careful rendering of three-dimensionality, the chiaroscuro use of colour, the highlighting technique.

However, this type of ceramics soon lost its creative inspiration and was reduced to a mannered production. In the following period, many of the typical characteristics of the beginning of the first phase disappeared or became much less evident. In addition, production of lesser commitment, probably intended for a different purchaser class or different use, soon emerged[10]. Among the nine ceramic specimens from Gnathia pottery in the Marchetti Collection, the focus is on the *kylix* CM 162 (*fig. 1*). The intact vessel[11] has a black, opaque, and evanescent covering in the Munsell Colour GLEY 2 3/1 (*very dark bluish grey*). It is not present on the outer base, the shelf and the outer wall of the foot. The decoration is concentrated exclusively on the inner base with a laurel branch overpainted in white that emphasises the animal figure (a hare) in movement. The author of this vase prefers a left-handed decoration of the laurel branch, typical of Apulian overpainted ceramics and not of Gnathian ceramics. The incrustations are again concentrated on the handles and the outer bottom of the vessel. The absence of a coating in some parts of the vessel indicates a lack of proper care, which is not typical of the production[12] period analysed. The doubts[13] raised by the archaeological investigation on the artefact's authenticity required a multidisciplinary approach to resolve any possible doubts.

METHODS: ACQUISITION

STRUCTURED LIGHT SYSTEM

High-speed 3D imaging technologies can be classified into two major categories: the passive and the active methods[14]. The structured light techniques belong to the active methods. They work projecting a specific predefined light pattern that covers the whole (or part of the) surface of the objects. These patterns can be simple multiple fringes of different colours (for example, black and white) or complex patterns with curves, either time or space coded. This scene is captured by a digital image detector and processed to reconstruct the geometry from the deformations of the patterns.

[8] MIŠE 2015; CALANDRA 2008.

[9] BORGNA 1990, p. 390.

[10] CIANCIO 1996, p. 395.

[11] Rim diameter: 12,55 cm; diam. of the bottom: 6,12 cm; height: 4,6 cm.

[12] CALANDRA 2006, pp. 654-655; VALLICELLI 2006, p. 251; REDAVID 2010, pp. 108-113.

[13] ZAMPARO 2019.

[14] LAZAROS, SIRAKOULIS, GASTERATOS 2008.

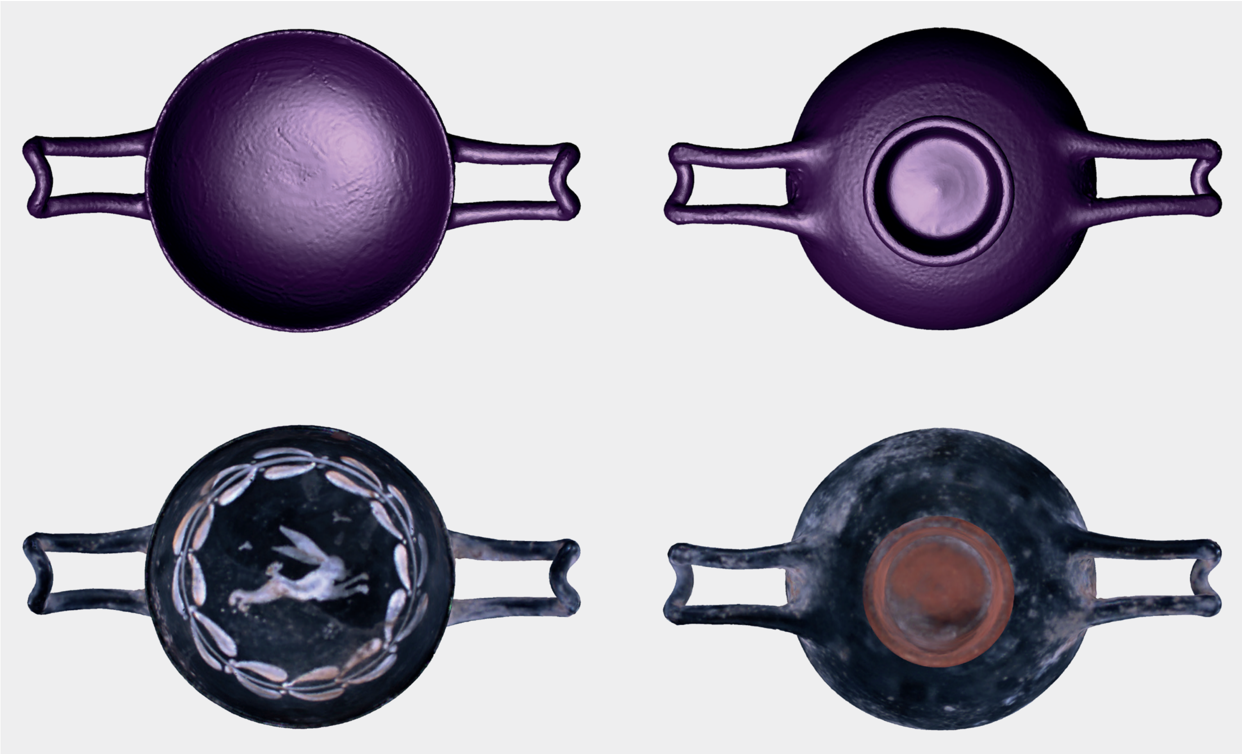

Fig. 3 – The kylix 3D high-resolution model was obtained through: the acquisition of partially overlapping range scans, the 3D data registration, the merge of the aligned range scans to produce a single digital 3D surface, and the mesh editing, which improves the quality of the model (topological mistakes, holes filling, and mesh simplification). By color mapping, color information is added to the geometry representation to produce a high-resolution photorealistic model in output.

This method is accompanied by texture acquisition and can lead to awe-inspiring results in terms of accuracy[15].

In this project, the instrument used for the acquisition is Cronos Dual, a structured light system by Open Technologies, with an accuracy of 10 ÷ 40 µm; camera resolution: 2 x 1.3 MPixels. The software used for the acquisition and post-processing of 3D data is Optical RevEng 2.4 SR 8 Pro (*fig. 2*).

High-Quality RTI acquisition

Reflection Transformation Imaging (RTI) has proved to be an exciting and powerful method to acquire and represent the 3D reflectance properties of an object, displaying them on a 2D image. RTI was first developed for use in association with Polynomial Texture Mapping (PTM) by Malzbender and colleagues in 2001[16].

For each pixel, the reflectance function is approximated by a biquadratic polynomial in the following way:

$$L(u, v, l_u, l_v) = a_0(u, v)l^2_u + a_1(u, v)l^2_v + a_2(u, v)l_u l_v + a_3(u, v)l_u + a_4(u, v)l_v + a_5(u, v)$$

where $(l_u l_v)$ is the direction of the incident light and (u, v) are the pixel coordinates. Hence, each pixel of a PTM image is composed of the RGB values and the six coefficients of the model function. Coefficients are calculated starting from a set of photos taken from a fixed point of view, with different

[15] Zhang 2018.

[16] Malzbender, Gelb, Wolters 2001.

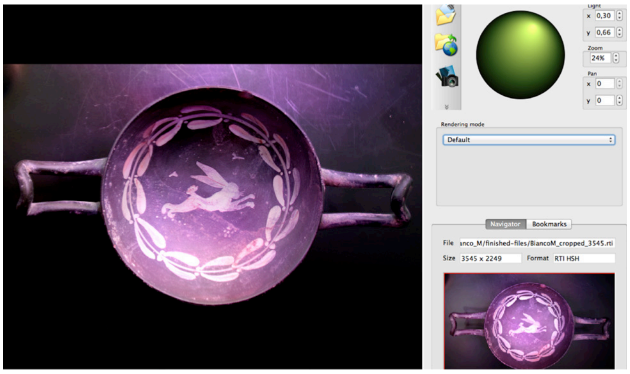

Fig. 4 – RTIViewer environment in default mode. The RTI visualization provides, in this case, the enhancement of the decorative pattern. Using the white light source, it is evident that the pigment used to draw the leaves responds differently. In particular, the pairs in the lower-left corner answer with higher brightness and this suggests the use of a different pigment. Screenshot by Emanuela Faresin.

light positions. In order to estimate the coefficients (a_0, …, a_5), the light positions have to be known.

In summary, RTIs are image-based representations of the appearance of a surface under varying lighting directions. Per-pixel surface normals are extracted from the representation and can be used to change lighting direction interactively and perform enhancements to make surface detail more visible. The transformations of these captured reflectance functions are calculated starting from a set of photos of the object, each one taken under controlled illumination. RTI is acquired by positioning the object of interest inside a light dome of fixed size. This permits to change of the light direction during photos acquisition automatically but limits the flexibility of the overall system. Since the size of our objects is too big to create a fixed dome, we decided to deal with a "virtual" light dome[17].

The RTI data set was collected with a Canon EOS 1200 D camera (technical characteristics: camera lens Sigma 18-250 mm f/3.5-6.3 AF DC macro), and a gold reflective sphere was used to detect the lighting angle in each photograph. RTIBuilder software (using Highlight Based, HSH Fitter, algorithm) combines them into a single file. The RTIViewer environment allows the output file to be virtually relit from any angle in different rendering modes as specular enhancement and standard visualisation as well as default (*fig. 3*).

RESULTS: LIGHTING FOR "DE-STRUCTURING" (POST PROCESSING)

DATA PROCESSING

The acquisition of the object was performed by taking a set of partially overlapping range scans to acquire many shots and produce the so-called range maps. The classical pipeline, which characterises a 3D scanning session, involves many different operations. Since most of the current scanning systems acquire only a portion of the artefact in a single shot, a complete 3D scanning requires the acquisition of many shots of the object taken from different viewpoints to gather complete information on its shape (geometry, topology and RGB information). The number of range maps requested to acquire an artefact depends on the surface dimension and the complexity of its shape. In this project, to guarantee better overlapping, an automatic turntable connected with the acquisition software was used. The rotation angle was set at 20° for each scan, and 18 scans for the set were made to complete the 360° rotation angle.

This range map set has to be processed to convert the data encoded into a single, complete, non-redundant and optimal 3D representation (a triangulated surface) (*fig. 3*). The processing phases (usually supported by standard scanning software tools) are:

- Range map alignment, to put all the single range map into a standard coordinate system where all the scans lie aligned on their mutual overlapping region. The pairwise ICP alignment algorithm, followed by a global registration, was used. An automatic pre-alignment technique was used during the acquisition phase to improve this task and verify the quality of the acquisition in real-time.

[17] DELLEPIANE *et alii* 2006.

- Range map merger (or fusion) to build a single, non-redundant triangulated mesh. After the registration, there are several partially overlapping meshes, one for each captured view. The next stage of the reconstruction pipeline must integrate them to build a single triangle mesh. There are several approaches for mesh integration: Delaunay-based methods, surface-based methods, parametric surfaces and volumetric methods.
- Mesh editing to improve the quality of the reconstructed mesh. The acquisition process may have incomplete or uncorrected areas. This step requires holes filling algorithms and editing topological mistakes (for example, cross-section triangles or odd vertices).
- Mesh simplification, to accurately reduce the massive number of triangles, producing 3D models with different high-quality Levels of Detail (LOD).
- Colour mapping enriches the information by adding colour information to the geometry representation, producing a 3D high resolution and photorealistic model[18].

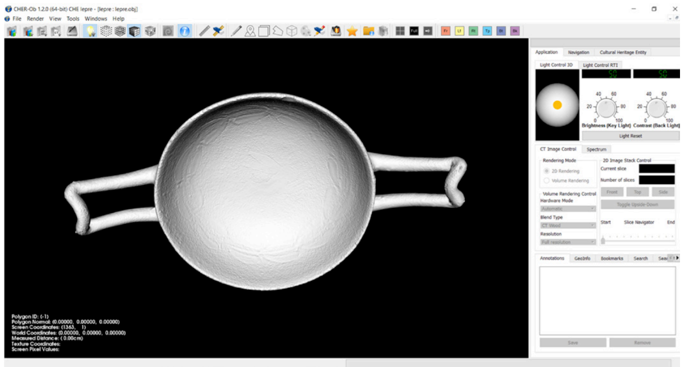

Fig. 5 – CHER-Ob integrating a system that allows users to visualize and annotate heritage data, produce a report or video, and summarize their results. It is a container of information about a cultural heritage object and serves as templates for researchers to build projects that address particular research questions. Screenshot by Emanuela Faresin.

Interactive Virtual Light

The use of PTM viewing software to interactively experience the virtual documentation of the artefacts demonstrates the value of reflection transformation imaging in archaeology. The ability to light vases from any desired direction allows seeing features from specific illumination directions. With a virtual PTM image, the formal study of "static photograph image" is transformed into a dynamic process of intentional viewing and exploring a rich data set intuitively. PTM illumination directions provide the most significant amounts of information in combination with specular enhancement, diffuse gain and standard visualisation. It allows scholars and other users to determine which image or set of images will most effectively communicate their ideas. The PTM image can be analysed both algorithmically and pragmatically to find the most advantageous combination of illumination angle(s) and enhancement effect(s) that illustrate the characteristics under discussion (*fig. 4*).

Moreover, 3D models were used virtual lighting environments, which provide robust analysis and evaluation functions for cultural heritage researchers (*fig. 5*). The main contributions of this software are:

Cultural Heritage Entity, a container with a hierarchical storage model of information about a cultural heritage object.

Annotation System with multiple selection mechanisms and colour encoding.

Automatic Report to generate a research report in pdf format, which summarises the project information.

Animation Schemes to realise an animated sequence for each user annotation[19].

The possibility of using a mobile virtual light on the 3D models allows to study the topological relationship between artefact (real/model) and radiant light, analyse the characteristics of the surface, and enhance specific details.

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[18] Scopigno, Cignoni, Montani 2007; Vrubel, Bellon, Silva 2009; Gomes, Bellon, Silva 2014; Zamparo, Faresin 2018; Rossi *et alii* 2019.

[19] Wang *et alii* 2018.

Discussion: a non-authentic vase

After the considerations developed in the previous pages, it appears necessary to verify the characteristics mentioned above regarding the non-authenticity of the CM 162 vase and other artefacts presumably belonging to the Gnathia-style pottery of the Marchetti Collection.

The study conducted confirms the non-authenticity of all the artefacts analysed. Several recurring characteristics can thus be identified, which can probably be traced back to a single workshop of forgers active in the Apulian area during the last century: the in-depth knowledge of some particular forms, present in the archaeological collections preserved in Lecce or Taranto, and the ability to combine the decorative repertoires of some of the most famous protagonists of Gnathia ceramic production, such as the "Painter of the Rose", the "Painter of the Louvre Bottle" or the "Group of the Dots Branch", are remarkable.

The chronology attributed to these forged artefacts also narrows down to a period between Middle Gnathia (330-300 BC) and the very early stages of Late Gnathia (300-250 BC).

All the preserved artefacts could be attributed to this workshop, with the necessary caution, although some doubts could be raised about the three *kylikes* (CM 161, 162, 163), which may be attributed to another hand.

On the technical-formal level, this forger(s) made a few mistakes:

1. red overpainting within the graffiti decoration, which is not attested in Gnathian ceramics or Gnathian style in any of the different productions;
2. metallescent yield of the surface due to excessively high firing temperatures compared to the firing methods used between the middle of the 4th and middle of the 2nd century BC;
3. the production of some moulds, according to a technique that was only rarely used in the period of production of Gnathia ceramics and, above all, used for undecorated material and uses other than symposia or ritual deposition;
4. selective placement of the incrustations in areas of the vessel usually devoid of decorations to give the artefact an appearance related to its presumably long history and, at the same time, not to excessively disturbing the taste of the possible buyer.

While these characteristics can be deduced even by the naked eye, by a suitably trained professional, the techniques described above allow the artefacts to be analysed through a wealth of detailed documentation, which is extremely useful for a "stratigraphic reading" of the artefacts' manufacturing and decorative methods.

Conclusions: a multidisciplinary approach for archaeological authentication

For the reasons discussed above, digital media open up new ways of engaging with shared cultural heritage.

This exploration of 2D and 3D reflection transformation imaging documentary applications indicate a strong affinity between structured light 3D acquisition and Reflection Transformation Imaging with PTMs.

The advantages arising from this affinity suggest that high-quality archaeological documentation can be produced through the joint application of these techniques. This multidisciplinary approach allows advantages on multiple fronts:

1. study of the archaeological material, specifically:
   - using hyper-realistic imagery (RTI) and 3D models to verify the dimensions, the presence of surface fractures and/or alterations and restorations of ancient or contemporary age, the application of surface decorations and their relative construction technique, and the study of the "stratigraphy" (as in the case of pictorial decorations rendered with a brush) of the creation of the object and its decoration;
   - studying macro- and micro-evidence on very high-resolution images;

2. implementation of accessibility to research through the creation of a virtual open-access database. In the wake of the teaching of Massimo Pallottino[20] who, as early as 1961, argued the importance of studying non-authentic material and the absolute necessity of its cataloguing and photographic archiving, it is now possible, thanks to the new technologies developed in recent decades, to create applications for the management of archaeological data that are, at the same time, a useful research tool for museums, experts, and the general public[21].
   Specifically, these new approaches make it possible to:
   - viewing materials that are inaccessible for reasons of ownership (public or private) and/or preservation (deposits with restricted access);
   - compare this data with archival materials to verify the authenticity of artefacts.

In conclusion, humanistic archaeological research, combined with new techniques of photographic analysis and 3D surveying, can finally be understood as a tool not only for the resolution of questions about the authenticity of allegedly archaeological objects but can also become an excellent tool, thanks to the substantial communicative impact of these approaches[22], for the dissemination of a new culture of legality in the historical, artistic, and archaeological field.

Giuseppe Salemi
University of Padova
giuseppe.salemi@unipd.it

Emanuela Faresin
University of Padova
emanuela.faresin@unipd.it

Luca Zamparo
University of Padova
luca.zamparo@unipd.it

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[22] Younan, Treadaway 2015.

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