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Digital Documentation and Virtual Accessibility of Prehistoric Artefacts: Case Studies from Sicilian Museums

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Abstract **– This paper addresses the challenges of documenting fragile prehistoric artefacts from three Sicilian museums, the Arturo Petix Civic Museum in Milena, the Civic Museum of Aidone, and the Paolo Orsi Archaeological Museum in Syracuse, through advanced 3D digitization techniques. Due to their delicate, fragmented nature and complex material properties, traditional documentation methods are often inadequate. Employing terrestrial photogrammetry and structured light scanning (NextEngine, Faro ScanArm, and Artec Leo), researchers successfully digitized 38 artefacts. This initiative significantly improves educational access and scholarly research capabilities, establishing an interactive virtual database and enhancing inclusivity through tactile 3D-printed replicas, especially benefiting visually impaired visitors.**

I. INTRODUCTION

Prehistoric archaeological artefacts present considerable challenges for researchers and museum professionals due to their fragile, fragmented, and often minuscule nature. These features complicate their handling, study, and conservation, as well as their effective communication to wider audiences. Traditional methods, such as photography or hand-drawn illustrations, frequently fall short in capturing the nuanced morphological or decorative details that are essential for interpretation and contextualization. Materials like ceramics, bone, or flint are especially sensitive to environmental conditions and physical manipulation, requiring careful conservation protocols. Compounding this, certain artefacts exhibit properties such as reflectivity or translucency, further obstructing accurate image-based documentation. In response, non-invasive digital recording techniques are increasingly necessary to produce high-resolution, precise models that preserve and reveal artefactual information often inaccessible through conventional methods. The interpretive challenge is equally significant. Static visuals rarely convey the original function or cultural relevance of these objects, particularly when they are incomplete or heavily deteriorated. This impairs both scholarly insight and public engagement, especially in educational or exhibit settings where dynamic, immersive experiences are most effective. To address these issues, this study employed advanced 3D digitization techniques to document 38 prehistoric artefacts housed in three Sicilian museums: the Museo Civico "Arturo Petix" in Milena, the Museo Archeologico Regionale di Aidone, and the Museo Archeologico Regionale "Paolo Orsi" in Siracusa. The resulting digital models have not only enhanced research capabilities but also created accessible, interactive resources that support inclusive education and heritage communication. This project demonstrates the critical role of digital tools in preserving and revitalizing Sicily's prehistoric past.

II. MATERIALS

In this study, artefacts made from stone (flint, basalt, limestone), terracotta (coroplastics) and pottery were selected due to their varying responses to digitization methodologies. Each material required a specifically chosen digital capture tool, resulting in highly effective documentation outcomes. Upon completion of the digitization process, digital collections comprising accurate 3D reproductions of prehistoric artefacts will be provided to three Sicilian museums to enhance educational accessibility and public engagement. The demand for realistic and precise 3D models of archaeological artefacts continues to grow, driven by their potential to significantly improve understanding and appreciation among diverse audiences. The Arturo Petix Civic Museum in Milena exhibits artefacts spanning from the Neolithic to modern historical periods, showcasing 7,000 years of local heritage. Digitization efforts included 12 prehistoric artefacts, notably ceramics and anthropomorphic clay idols, with selected items reproduced using 3D printing technologies. The Civic Museum of Aidone, situated

within a former Capuchin convent, primarily displays finds from excavations at Morgantina. Here, 21 artefacts, including lithic tools made from flint and basalt and various pottery items dating from the Neolithic to Iron Age periods, were digitized to facilitate enhanced educational and interpretive experiences. The Paolo Orsi Archaeological Museum in Syracuse, a prominent Sicilian institution established in 1878, houses an extensive collection of over 20,000 artefacts. The digitization project at this museum focused on five significant prehistoric items, including two Early Bronze Age stone tomb-sealing panels with anthropomorphic carvings and three ceramic vessels from the Middle Bronze and Iron Ages. This initiative aims to provide detailed, interactive digital access, significantly enhancing public and scholarly engagement with these historically important collections [1].

III. METHODS

In order to identify the best methodological approach to 3D digitize prehistoric archaeology artefacts [2], four different 3D digitization methodologies were applied in this research: a NextEngine triangulation laser scanner (Fig. 1), a Faro 8-Axis Design ScanArm 2.5C laser scanner (Fig. 2), an Artec Leo structured light 3D scanner (Fig. 3), and terrestrial digital photogrammetry. A NextEngine triangulation laser scanner was employed for high-precision surface scanning of small- to medium-sized objects with detailed geometric features. The scanner utilized laser triangulation technology operating with a 650 nm red laser diode, capable of capturing data at a resolution of 0.127 mm with an accuracy of ±0.1 mm. Objects were positioned on an automated rotary stage, enabling scans at various angles, and subsequently aligned and merged using ScanStudio HD Pro software. A Faro 8-Axis Design ScanArm 2.5C laser scanner was utilized to digitize objects requiring higher precision and flexibility in data capture. This articulated arm scanner featured a blue laser line probe with a measurement accuracy of up to ±0.025 mm. Objects were digitized through multiple overlapping passes at a scanning rate of approximately 560,000 points per second, with the object mounted on a rotating platform enabling comprehensive coverage. Post-processing and mesh optimization were carried out using Faro's proprietary CAM2 software suite. The Artec Leo structured light scanner served to digitize medium-sized artifacts characterized by intricate decorative features. The scanner employed structured white-light technology, effectively capturing surface details from a distance ranging between 60 and 120 cm. Default scanning settings were applied, and post-processing was conducted in Geomagic Wrap 2021 software. The resulting scans accurately recorded fine surface engravings and subtle textures, facilitated by advanced texture mapping algorithms, allowing detailed analysis of features typically difficult to detect visually. Terrestrial digital photogrammetry was applied primarily for capturing accurate 3D documentation of low-reflectance objects, particularly those composed of clay. Thousands of images were collected using a Canon EOS 2000D camera paired with a Sigma 10-20 mm f/4-5.6 EX DC HSM wide-angle lens, fixed at a focal length of 10 mm with an aperture of f/8. Image preprocessing, including white balance, color adjustment, and lens distortion correction, was performed using Adobe Lightroom Classic. Subsequently, image alignment, dense point cloud creation, and textured mesh generation were completed using Agisoft Metashape and 3D Zephyr Fluo software suites. The main purpose of relying on digital photogrammetry was that of generating high resolution realistic textures to map, if and when necessary, on the meshes created by the 3D scanners.

Fig. 1. NextEngine triangulation laserscanner in use at the Museum of Siracusa.

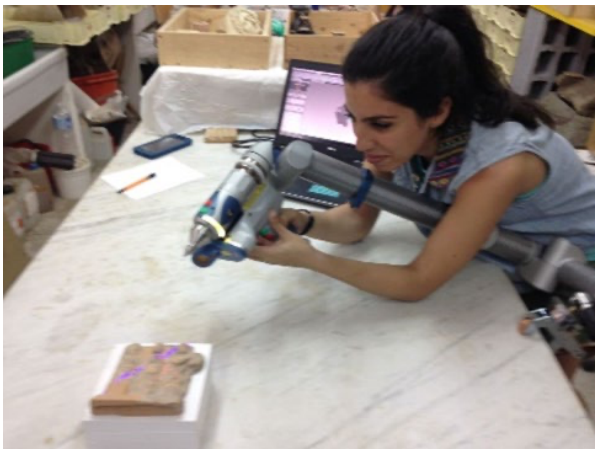

Fig. 2. A Faro 8-Axis Design ScanArm 2.5C laser scanner in use at the Museum of Aidone.

Fig. 3. Artec Leo 3D scanner in use at the Museum of Milena.

Lighting conditions in the storages and the galleries of the three museums, a combination of strong natural light sources with diffuses and/or concentrated sources of artificial white and yellow light, significantly impact terrestrial photogrammetry and structured light scanning. Suboptimal lighting environments may result in incomplete models, especially during the texturing phase. This issue is particularly common in museums, which typically lack the uniform lighting systems necessary for optimal digital documentation. To mitigate such problems, significant post-processing efforts may be required, or alternative scanning methodologies affected by lighting conditions can be implemented. Additionally, highly reflective materials like flint pose challenges for photogrammetry due to difficulties in image alignment during processing. The Faro 8-Axis Design ScanArm 2.5C laser scanner appeared to be unaffected by the lighting issues and was successfully employed to accurately digitize small, thin objects, including flint tools, capturing intricate details and ensuring robust results despite challenging material properties. As a final step of the project, 3D printing was employed to create digital replicas for public outreach and pedagogic activities. An Anycubic Photon Mono X printer, a high-resolution resin 3d printer with a pixel resolution of 3840 x 2400 was used to generated 3D prints with Elegoo Resin, which is known for their ductility and water washability. This resin is designed for 1000-gram LCD 3d printing, with a standard wavelength of 405 nm. The first step in the printing process was transferring the 3d models into the FlashPrint software. This software helped optimize the available space inside the printer by adjusting it to the shapes of the objects during the programming phase. Ultimately, we produced prints identical to the originals and highly durable, capturing even the finest details of the objects accurately (fig. 4) [3].

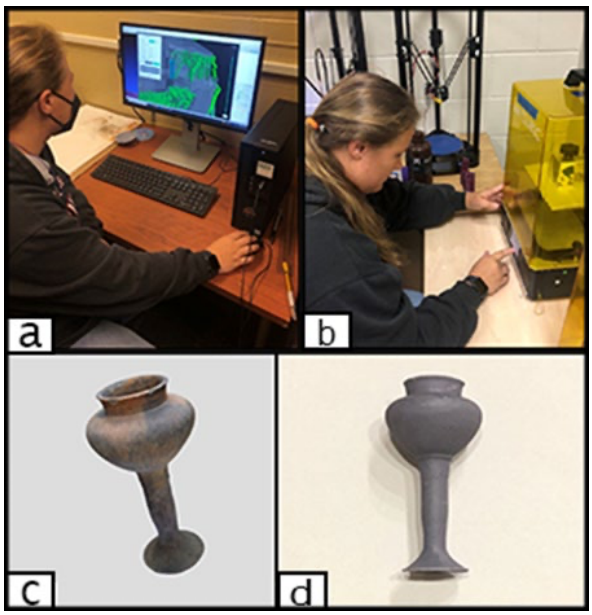

Fig. 4. Preparation of the 3D data with FlashPrint software; c) 3D model made with Artec Leo of an Iron Age vessel from Milena; d) 3D printed model.

IV. DISCUSSION

Terrestrial photogrammetry is highly suitable for digitizing small- to medium-sized clay objects due to their generally regular shapes and matte surfaces. However, this method encounters significant limitations when applied to reflective materials or complex geometries prone to producing excessive shadows. Artefacts composed of flint, metal, or possessing irregular forms often present difficulties for photogrammetric techniques, resulting in incomplete or inaccurate 3D models and necessitating extensive post-processing. Consequently, structured light scanning was employed to mitigate these limitations. In addressing these challenges, an Artec Eva structured light scanner was utilized, providing superior outcomes for reflective surfaces and poorly illuminated environments. This scanner produced high-resolution models with realistic textures, enabling detailed analytical investigations. Nevertheless, the Faro 8-Axis Design ScanArm 2.5C presents notable constraints, including reduced portability and suboptimal performance when digitizing extremely small objects such as coins or miniature ceramic and flint artefacts. To overcome these limitations, the Artec Leo structured light scanner, designed explicitly for high-precision digitization of small, thin objects, was adopted. The Leo's portability and accuracy facilitated successful 3D reconstructions of artefacts otherwise problematic for other scanning devices. By integrating multiple digitization methodologies, this study established a virtual exhibition that assembles physically dispersed artefacts from various Sicilian museums into a cohesive thematic collection. This virtual

environment categorizes prehistoric archaeological artefacts according to typology and chronology, significantly enhancing scholarly access and comparative analysis capabilities. Additionally, this multimedia approach fosters broader public engagement, allowing wider audiences to explore and understand artefacts virtually, leveraging an ad hoc Sketchfab collection (Figs. 5-7), safeguarding the original, delicate items from physical handling. The project's objectives encompassed both educational and research dimensions.

Fig. 5a-b. Milena Museum, a) 3D model of a Middle Neolithic terracotta anthropomorphic figurine, Camaro type; b) 3D model of a Middle Neolithic painted jar.

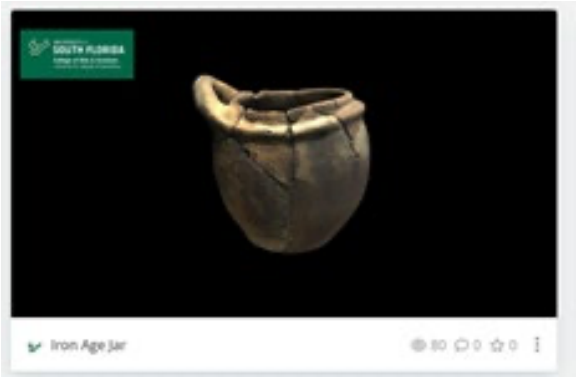

Fig. 6a-b. Aidon Museum, a) 3D model of Early Bronze Age basalt hand axe; b) 3D model of Early Iron Age bowl.

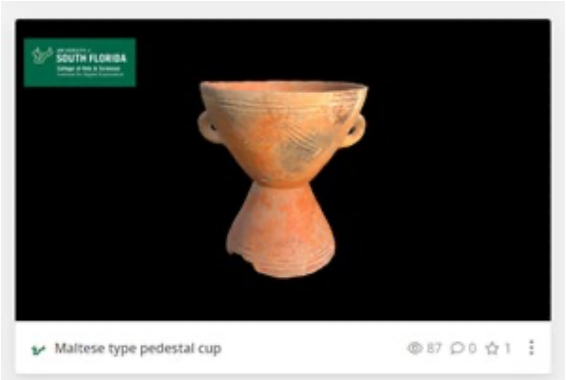

Fig.7a-b: Siracusa Museum, a) 3D model of an Early Bronze Age funerary stone panel; b) 3D model of a Middle Bronze Age pedestal cup of Maltese type.

Digitally interacting with precise 3D replicas considerably enhances educational experiences, facilitating deeper comprehension of artefacts for students and scholars alike. Moreover, the research aimed to evaluate and refine methodological workflows, identifying optimal digitization techniques tailored to artefacts' material composition and morphological complexity. Long-term goals include the creation of an expansive, interactive 3D database, enabling comprehensive remote

analysis and comparisons of Sicilian prehistoric collections and promoting greater inclusivity through tactile interactions via 3D-printed replicas, particularly beneficial to visually impaired visitors.

V. CONCLUSION

Using terrestrial photogrammetry and two types of structured light laser scanners, we have produced over 40 3d models of archaeological artefacts from three museums in Sicily. This digital collection effectively represents the various phases of the island's prehistory and serves scholars for research and enthusiasts.

While creating this collection, we encountered several challenges, particularly in selecting the appropriate capture tools based on the ancient artefacts' nature, shape, and material. Ultimately, we developed a workflow that utilises terrestrial photogrammetry for regular form, and medium-sized clay objects, the Artec Eva structured light scanner for medium-sized objects with irregular shapes and intricate decorations, and the Spider structured light scanner for small objects with reflective surfaces, such as small flint artefacts.

This work has allowed us to produce prints identical to the originals, making museums more inclusive and accessible to diverse audiences. The future goal is to gather additional 3d models from various museums to create a comprehensive multimedia catalogue of Sicilian prehistory that can be easily accessed remotely.

This study successfully demonstrated the effectiveness of integrating terrestrial photogrammetry and structured light scanning technologies to digitally document fragile prehistoric artefacts from three Sicilian museums. By addressing methodological challenges related to artefact size, material, and reflectivity, the research has established a robust workflow tailored to diverse archaeological contexts. The resulting detailed and interactive 3D models significantly enhance scholarly analysis, public engagement, and educational inclusivity. Ultimately, the creation of an accessible virtual collection and the implementation of tactile 3D-printed replicas not only safeguard Sicily's delicate archaeological heritage but also promote broader and more inclusive cultural appreciation.

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