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Preliminary Results of the Integrated 3D Digitization of the Prehistoric Artifacts Exhibited at the Museum of Archaeology of the University of Catania

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Abstract – **This paper presents the preliminary results of an in-situ three-dimensional digitization campaign carried out on 41 artifacts from the Museum of Archaeology of the University of Catania, with a particular focus on prehistoric materials representative of early Sicilian cultures. Conducted within active exhibition spaces illuminated by 5500 K LED fixtures and indirect natural daylight, the protocol employed a sequential workflow integrating structured–light scanning and calibrated photogrammetry. A single reference capture of an X-Rite ColorChecker Classic per artifact enabled the derivation of bespoke color profiles, harmonizing texture generation across varying ambient conditions. Metric scaling was achieved via coded targets in Agisoft Metashape, facilitating 1:1 dimensional reproduction and quantitative error analysis. Post–processing in Artec Studio and other specialist software refined mesh quality and chromatic consistency. These findings confirm that scientifically rigorous, reproducible digitization protocols can be effectively implemented in conventional museum environments, producing high–fidelity digital surrogates to support typological research, preventive conservation, and immersive public engagement.**

I. INTRODUCTION

In recent years, the digital preservation of cultural heritage has emerged as a multidisciplinary imperative, spanning fields from archaeology and museum studies to digital humanities and information science [1, 2, 3]. Three-dimensional (3D) digitization enables the creation of precise digital surrogates that safeguard artifacts against deterioration, facilitate remote scholarly collaboration, and support immersive public engagement [4, 5]. Digital archives also stimulate novel research avenues, such as morphometric analysis, virtual restoration, and material characterization, while underpinning preventive conservation strategies and heritage management frameworks [6, 7].

Despite these advances, many museum digitization efforts remain predominantly visually oriented, prioritizing photorealistic renderings for exhibition over rigorous scientific validation. This emphasis often overlooks critical aspects of metric accuracy, standardized workflows, and reproducible calibration protocols, thereby limiting the potential of 3D models as quantitative research tools. Although several studies have addressed methodological robustness in cultural heritage digitization [8, 9], the gap between visual fidelity and scientific rigor persists. Recent contributions have emphasized the importance of systematic calibration protocols [10], robust 3D-2D data integration workflows [11], and provenance tracking systems [12] to ensure scientific reproducibility and reliability.

This paper presents a case study conducted at the Museum of Archaeology of the University of Catania (MAUC), and part of the University Museum System (SIMUA). Our work focused on a selection of 41 artifacts, representing all chronological periods from early prehistory to the Roman era, with an emphasis on Neolithic and Bronze Age artifacts selected for their diagnostic and typological significance. By integrating structured-light scanning (Artec Eva) and terrestrial photogrammetry (Canon EOS RP) under controlled acquisition parameters, we aim to establish a validated, replicable workflow that addresses both visual and scientific requirements for museum-grade digitization.

II. MATERIALS

The MAUC houses a permanent collection of 325 artifacts, originally part of the collection donated in 1953 by former rector Guido Libertini to the University of Catania. The core of the collection consists of classical antiquities

Fig. 1. A glimpse into the first room of the Museum of Archaeology of the University of Catania (MAUC).

gathered by Libertini himself, later enriched by additional finds unearthed during the archaeological activities conducted by the University's Institute of Archaeology. The artifacts span a broad chronological range, from prehistoric assemblages (including Neolithic and Bronze Age ceramic vessels) through the Greek and Roman periods, up to Late Antiquity and the Medieval era, offering a comprehensive overview of the material culture of the Catania region (fig. 1). The collection features a wide variety of archaeological materials, including pottery, metal objects, inscriptions, terracotta figurines, coins, and more. Notably, it also includes approximately 80 high-quality forgeries dating to the first half of the 20th century. These comprise retouched polychrome vases, complete forgeries of vase paintings, executed on both ancient and modern supports, as well as forged terracottas and modern replicas produced using authentic ancient molds [13].

For this pilot study, 41 artifacts (approximately 12.6 % of the total) were carefully selected to reflect the museum's chronological span, material diversity, and state of preservation. Selection criteria prioritized items that exemplify key typologies, with a deliberate inclusion of prehistoric ceramics and figurines, chosen for their morphological complexity and surface variability as well as those presenting distinct surface conditions such as glossy coatings, micro–cracks, and patinated finishes. Particular attention was given to prehistoric artifacts, which pose significant challenges for digitization due to their delicate consistency, fragility, color variations, and fragmentary nature. These factors present difficulties for both laser scanning and photogrammetry technologies. To evaluate metric fidelity, one objective of this study was to reproduce select artifact dimensions at a scale 1: 1 scale using local coordinate systems defined by coded targets, and to quantify the resulting deviations. This approach established a baseline for error analysis and informed calibration protocols for subsequent acquisitions.

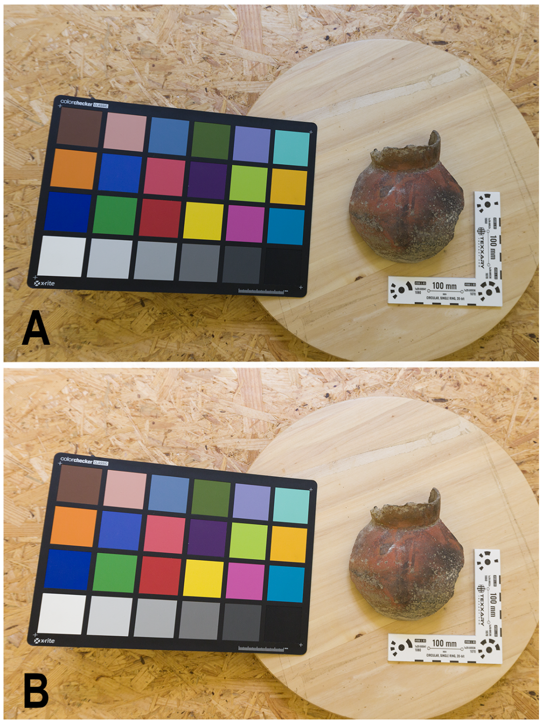

Fig. 2. Color calibration on a Sicilian Bronze Age painted pottery (inv. 4). In A) the original RAW file; in B) the result of automatic color calibration using Calibrite Profiler software.

III. METHODOLOGY

The spatial constraints common to in–situ operations, particularly within enclosed museum galleries, precluded the establishment of a dedicated, light–controlled studio. Instead, digitization took place within the existing exhibition spaces, illuminated by low–consumption fluorescent fixtures calibrated to a daylight effect (approximately 5500K), complemented by indirect natural light entering through large windows. To mitigate the dynamic interplay between artificial and ambient daylight, most pronounced at different hours, a single reference image including the X–Rite ColorChecker Classic was captured at the start of every single dataset acquisition. This reference, displaying 24 standardized color patches and an 18 % gray target, provided the basis for generating a bespoke color profile (fig. 2). The resulting corrections (white balance, tone curves, and saturation adjustments) were uniformly applied to the entire RAW dataset for each artifact, ensuring consistent colorimetric integrity across textures derived from both photogrammetric and scanner data [14].

Each artifact underwent a double stage acquisition pro-

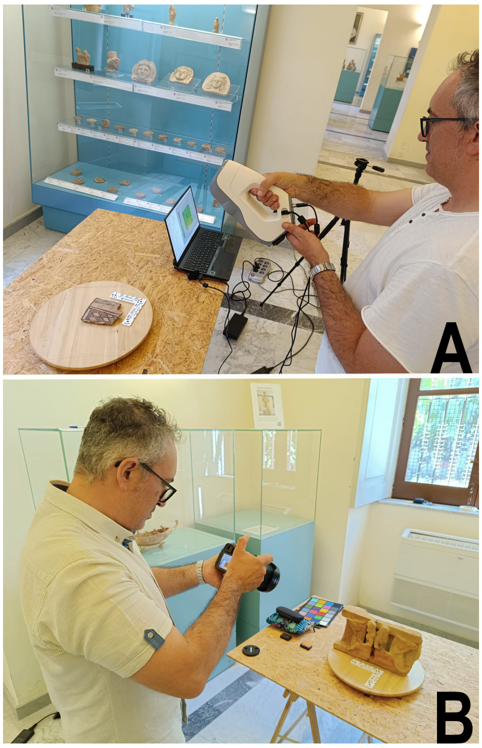

Fig. 3. Dataset acquisition using light-structured laser scanner (A) and photogrammetric tecnique (B).

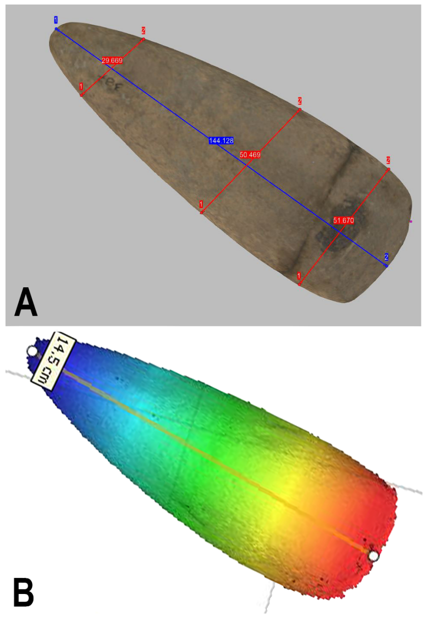

Fig. 4. Comparison of measurement methods on 3D a model (inv.3): A) Linear dimensions extracted from a high-resolution 3D mesh generated by a structured-light laser scanner; B) Corresponding measurements taken on a photogrammetry-derived 3D object, scaled using local reference coordinates.

cess carried out sequentially to maintain unaltered environmental conditions for that specific object. First, structured–light scanning was performed using an Artec Eva device, capturing high–density point clouds with embedded texture information. Immediately following, high–resolution photographic images were acquired with a Canon EOS RP, fitted with a 16–35mm f/4.0 lens, to record surface detail in calibrated color (fig. 3). The inclusion of the ColorChecker in both modalities allowed the same color management workflow to be applied to scanner textures.

Following capture, raw datasets were processed using Artec Studio 19 for point cloud registration, mesh reconstruction, and initial texture mapping. Concurrently, photogrammetric sequences were imported into Agisoft Metashape 2.2.0, where coded targets defined local coordinate systems to scale models at 1:1. Metric calibration based on these targets facilitated the quantification of dimensional error in subsequent validation (fig. 4). Finally, optimized meshes and calibrated textures were refined in Blender 3.6 or in Geomagic Wrap 2021 software (for meshes) and Adobe Substance Painter (for texture), employing noise reduction filters and UVmapping corrections, to yield final 3D models with both scientific accuracy and consistent visual quality.

IV. DISCUSSION

The validation phase of the dual-acquisition protocol employed at the Museum of Archaeology of the University of Catania confirmed the method's capacity to deliver high-fidelity 3D documentation under non-laboratory conditions. Digital measurements extracted from both structured-light and photogrammetric models exhibited a mean deviation of 0.12 mm ($\sigma = 0.04mm$) when compared to micrometric caliper readings. This performance reflects the complementary strengths of the technologies used: structured-light scanning ensured dense geometric coverage, while photogrammetry contributed high-resolution chromatic detail essential for surface texture fidelity (fig. 5) [15].

To mitigate inconsistencies introduced by fluctuating lighting conditions, particularly under mixed 5500 K LED and diffuse natural light, color calibration was conducted using a single-reference ColorChecker workflow. This procedure maintained chromatic consistency across acquisition sessions, validating the viability of performing color–accurate digitization in active museum settings without dedicated studios [16].

Moreover, the sequential acquisition strategy, capturing scanner and photographic data in immediate succession, minimized temporal drift between geometric and chromatic datasets. The integration of coded targets within

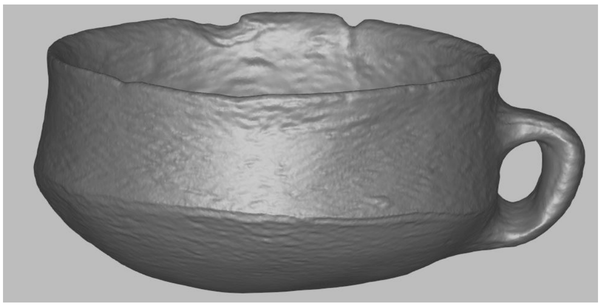

Fig. 5. A sample of high-quality mesh acquired with Arterc Eva and processed in Artec Studio 19. Bronze Age prehistoric cup (inv. 10).

Agisoft Metashape further enabled precise metric scaling, achieving an average spatial accuracy of $0.0001m(XY)$ and $0.0002m(Z)$, thereby supporting morphometric and analytical applications [17].

These results substantiate the methodological reliability and practical adaptability of the proposed digitization workflow. The framework not only ensures metric and photometric reproducibility but is also modular, facilitating the integration of future enhancements such as multispectral imaging and automated feature recognition algorithms [17, 18].

V. CONCLUSION

The integrated dual-acquisition protocol implemented at the Museum of Archaeology of the University of Catania has demonstrated that achieving high geometric fidelity and chromatic consistency under in-situ conditions can enhance the realistic perception of digital museum artifacts, while also providing valuable tools for academic research and study. By synchronizing structured-light scanning and calibrated photogrammetry within active exhibition spaces, and applying rigorous colorimetric and metric calibration workflows, the methodology proved effective in generating scientifically robust digital surrogates. Particular emphasis was placed on prehistoric artifacts, including Neolithic and Bronze Age ceramics, which present specific challenges due to their surface porosity, chromatic variability, and morphological fragility. The ability to acquire millimetric geometric detail and true-to-life textures in these complex materials validates the approach as suitable for documenting highly sensitive archaeological objects. The resulting 3D models not only support typological and morphometric studies, but also offer a reliable basis for comparative research, preventive conservation, and virtual dissemination strategies. This makes the workflow particularly valuable in the field of prehistoric archaeology, where the integration of accurate 3D documentation can enhance knowledge dissemination and public engagement with early human material culture.

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