

# High-Resolution 3D Surveying to Support Museum Inclusiveness Strategies

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**Abstract** – In recent years, there has been a notable increase in attention and efforts directed toward enhancing inclusivity in the dissemination of cultural heritage. This trend is being observed across museums and cultural institutions worldwide, which are actively adopting a variety of innovative strategies to make their collections and assets more accessible to diverse audiences. A wealth of examples has emerged showcasing facilities that have been specifically designed for individuals with disabilities, highlighting a growing commitment to inclusiveness in cultural spaces. In particular, within the context of visual impairment, museums have successfully implemented tactile replicas of artworks and archaeological artifacts. These replicas enable visitors to touch and engage with the physical forms, allowing them to perceive the geometry, texture, and materials of an object in ways that foster greater understanding and appreciation. This study proposes an innovative and forward-thinking approach that leverages high-resolution geomatic surveys, employing structured light projection scanning technology, to reconstruct significant archaeological artifacts digitally. By utilizing these advanced methods, the aim is to provide museums not only with digital models but also with the means to create physical, high-fidelity replicas using cutting-edge 3D printing technologies. This initiative is part of a broader museum inclusivity project being collaboratively executed by the municipalities of Rimini and Riccione in Italy. Through this innovative endeavor, we aim to bridge the gap between cultural heritage and accessibility, ensuring that all visitors, regardless of their physical abilities, can engage with and experience the richness of our shared past in a meaningful and inclusive manner.

## I. INTRODUCTION

In recent decades, museums have shifted their focus from being institutions primarily dedicated to preservation

and safeguarding of artifacts to becoming spaces of active audience engagement and participation.

This evolution reflects a broader rethinking of the museum’s role in society, moving from object-centered approaches to visitor-centered strategies that prioritize learning, experience, and social inclusion. Among the emerging priorities shaping this transition is inclusivity – the commitment to ensuring that all visitors, regardless of their sensory, physical, or cognitive abilities, can access, interpret, and experience collections in a meaningful and autonomous way (Ciaccheri, 2022), (Sawczuk, 2024). This objective is now considered central to the ethical responsibilities of museums, as accessibility is increasingly recognized not merely as a compliance requirement but as an integral aspect of audience development and cultural democracy (Starr, 2016).

Technological advances in recent years, particularly in the domains of three-dimensional (3D) high-resolution surveying (Bitelli et al., 2022), (Forte et al., 2023) and additive manufacturing, have opened new pathways for museums to achieve inclusiveness aims more effectively (Brischetto et al., 2023), (Gatto et al., 2025). These technologies, originally introduced for documentation and conservation purposes, are now enabling innovative forms of interpretation and engagement, facilitating experiences that were previously inaccessible to certain visitor groups.

Applications of this kind consist in the creation of virtual exhibitions or online databases, or the production of tactile resources and replicas specifically designed for visually impaired users (Mesquita & Carneiro, 2016), (Sun et al., 2023). Replicas produced from high-accuracy digital models can enable detailed tactile exploration of shapes, surfaces, and iconography, fostering greater autonomy and connection with museum collections for blind and visually impaired visitors.

Notably, recent Italian implementations illustrate the potential of combining 3D scanning and printing with user-centered design. At Palazzo Bo in Padova, researchers employed a “saliency-driven” scanning and

printing workflow to reproduce Coats of Arms with variable levels of detail, guided by visual attention models to enhance tactile legibility for visitors with visual impairments (Sofica et al., 2024). Similarly, the Palatine Museum in the Colosseum Archaeological Park, Rome, has established a tactile path featuring 3D-printed replicas of archaeological artifacts—such as an antefix, mosaic, and sculpted head—created through structured-light scanning and printed in materials that mimic the original textures (Colosseum Archaeological Park website, 2020).

In this context, the present study examines museum strategies aimed at promoting inclusivity, using a recent project conducted at the Territory Museum of Riccione as a detailed case study. The article outlines the workflows, methodological approaches, and technological considerations involved in producing tactile museum replicas through high-resolution three-dimensional surveying and printing. It also discusses how geomatics-based strategies can support institutional goals related to accessibility and educational engagement within museum settings.

### 1.1 Case Study: The Territory Museum of Riccione

The Territory Museum of Riccione, Italy, an institution dedicated to preserving and showcasing archaeological finds originating from Riccione and the wider Conca Valley area, has recently undertaken a project with the specific aim of enhancing inclusivity and accessibility for its diverse visitor base. Recognizing the importance of making its collections and exhibitions meaningful and engaging for all audiences, the museum initiated an initiative focused particularly on tactile exploration as a strategy to overcome sensory barriers, especially those of visually impaired users.

As part of this initiative, the museum involved the Geomatic group of DICAM (Dept. of Civil, Chemical, Environmental and Materials Engineering) of Bologna University, to develop and produce a series of three-dimensional (3D) printed replicas of selected archaeological artifacts. These replicas were integrated into an interactive installation created by La Jetée LTD company, which was conceived as a tactile route that conceptually and physically replicates the ancient Via Flaminia, a Roman road of significant historical importance that traversed the region.

Key artifacts selected for replication within this project included decorative slabs depicting iconographies such as Winged Victories and Potnia Theròn figures, both dating back to the first century BC, which are characterized by their intricate reliefs and artistic detailing. Additionally, the installation features a series of artifacts conserved at Rimini (Italy) Archaeological Museum: a Roman milestone bearing inscriptions from different historical periods, two fictile decorative slabs, a “Captive Celt” high relief, and a marble inscribed table containing textual evidence of past societies (Belfiori, 2024).

## II. METHODOLOGY

### 2.1 High-resolution 3D and 2D data acquisition

The scanning strategy employed two structured light scanners: the Artec Eva, with a nominal accuracy of 0.1 mm for general geometry acquisition, and the Artec Spider, offering an accuracy of up to 0.05 mm for detailed surface features (Artec3D, 2025). Data acquisition required 15–20 minutes per object for Eva and additional time for Spider’s detailed scans.

High-resolution images were captured using a Sony DSC-RX100M7 mirrorless camera (20.1 MP, 1” CMOS sensor) to create accurate texture maps. Both nadir and oblique images were acquired, maintaining 80% overlap to ensure comprehensive coverage. Although photogrammetry was initially considered for geometric reconstruction, structured light scanning yielded superior accuracy for complex morphology, and photographs were primarily used for texturing (Bitelli et al., 2025).

### 2.2 Data processing workflow

Processing was conducted in Artec Studio Professional, the proprietary software associated with the scanners employed. Individual scans were aligned and registered using ICP (Iterative Closest Point) algorithms before being merged into unified 3D meshes (Fig. 1). For each artifact, a realistic texture was generated using high-resolution images, although this step was not required for three-dimensional printing. This was accomplished using the photo-registration algorithm in the Artec proprietary software, which projects and maps two-dimensional images onto the geometric models.

Subsequently, to optimize the models for 3D printing, remeshing procedures were performed to ensure uniform polygon distribution, thereby eliminating topological irregularities. Final models (an example is shown in Fig. 2) were downscaled from an initial resolution of 0.1–0.2 mm to 0.3 mm, sufficient for tactile replica production and to preserve surface details while reducing file sizes for manageable printing.

While inclusivity formed the project’s core, as detailed in the following sub-section, the digital models also facilitated further analyses:

- Fragments of *Potnia Theròn* slabs were digitally reassembled, revealing their original composition, with a so-called “virtual restoration” approach;
- The *Damnatio Memoriae* marble slab was processed with shaders and filters to enhance legibility of erased inscriptions, enabling partial reconstruction.
- The milestone’s cylindrical surface was unrolled digitally, facilitating reading of inscriptions otherwise challenging to interpret on curved surfaces.

These operations—better detailed in Bitelli et al. (2025) along with the surveying and processing procedures—demonstrated the expanded utility of high-resolution digital models, enhancing research and interpretation.

### 2.3 Implementation of the tactile experience

For the museum's inclusiveness project, digital models were transformed into physical replicas to create a tactile route along the ancient Via Flaminia. The installation was designed and executed by La Jetée in collaboration with the Italian Union of the Blind and Partially Sighted and the association La Girobussola, aiming to enable visually impaired visitors to trace the route with their fingertips (Fig. 3). Visitors encounter the printed models positioned according to their original archaeological findspots, reinforcing each artifact's historical context. Integrated

audio descriptions provide interpretive and historical insights, further enriching the experience.

Replicas were produced using Digital Light Processing (DLP) printing at a resolution of 0.3 mm to capture minute inscriptions and decorative elements accurately. Most items were printed at 1:2 scale to optimize tactile readability and integrate seamlessly within the exhibition design, while the Ariadne and Dionysus slab was reproduced at a 1:1 scale to retain its intricate reliefs. The platform was tested during an opening ceremony and is now accessible to all visitors (Fig. 4).

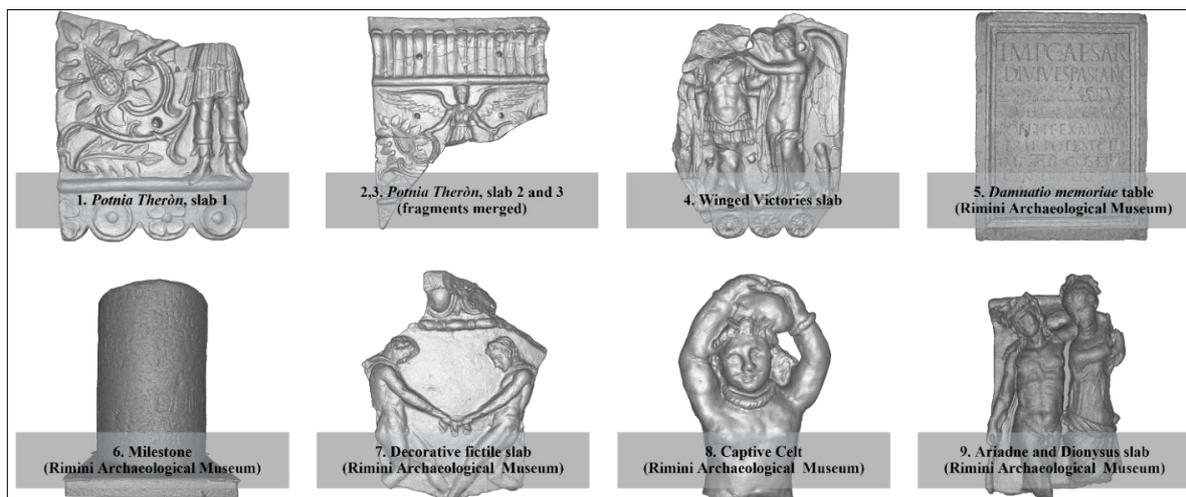


Figure 1. 3D models of all the reconstructed objects (unt textured, original resolution 0.1 - 0.2 mm)

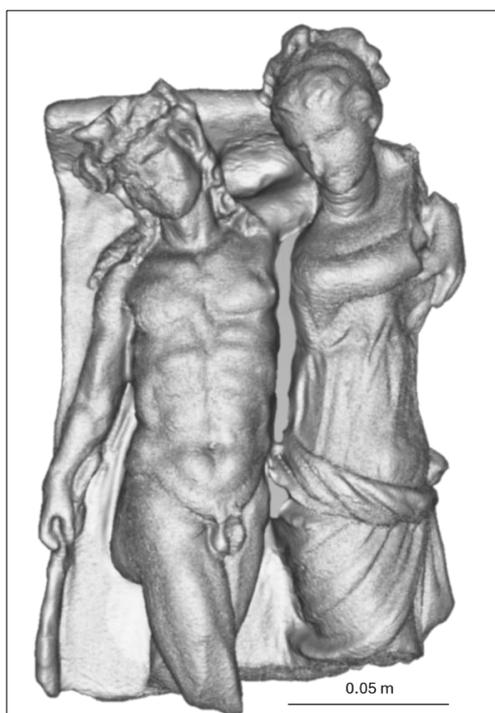


Figure 2. Detail of Ariadne and Dionysus 3D model (0.3 mm resolution)



*Figure 3. The implemented platform with the physical replicas inside the museum*



*Figure 4. Testing the platform during the opening ceremony at the museum*

### III. DISCUSSIONS AND CONCLUSIONS

This study demonstrates that integrating high-resolution 3D surveying with additive manufacturing offers practical applications for improving museum accessibility. Although these digital technologies were initially adopted for documentation, conservation planning, and virtual archiving, recent developments have extended their use to the production of tactile replicas, supporting inclusiveness initiatives.

The Riccione Museum project effectively illustrates this application. Using accurate and detailed 3D models obtained through photogrammetry and laser scanning, tactile replicas were produced with additive manufacturing techniques. These models enabled visitors with visual impairments to explore the morphological features, spatial configurations, and decorative elements of artifacts through touch, which would not have been possible with the original artifacts due to conservation and safety restrictions.

Preliminary user feedback collected during the opening ceremony indicated that the tactile route supported visitors' spatial orientation and understanding of the artifacts' geometric properties, dimensions, and surface details. Such results suggest that combining high-resolution 3D data acquisition with precise additive manufacturing can provide reliable solutions to enhance accessibility in museum environments while preserving the morphological accuracy required for meaningful tactile interpretation.

However, some considerations emerge for future research and practice:

- Evaluating user experiences systematically: While initial qualitative feedback was positive, a rigorous evaluation involving larger samples of visually impaired users is essential. Studies focusing on user preferences, cognitive mapping strategies, and ergonomic requirements will refine replica design, layout, and interpretive frameworks, thereby enhancing usability, comfort, and learning outcomes across diverse visitor groups.
- Assessing replica fidelity quantitatively: The accuracy of replicas is critical for effective tactile interpretation. Comparative geometric analyses, such as rescanning printed models and aligning them with original digital meshes, can quantify dimensional accuracy and surface fidelity. This ensures that tactile replicas maintain morphological integrity, particularly when sub-millimeter decorative details carry artistic or pedagogical significance.
- Integrating advanced multisensory technologies: Future inclusiveness projects could incorporate haptic feedback systems or augmented reality (AR). Haptic devices can simulate material properties, resistance, or dynamic interactions, while AR overlays may provide

synchronized spatial or contextual information. Such integrations could create cohesive interpretive narratives that combine touch, sound, and visual data to support complex learning objectives and personal meaning-making.

- Considering material properties and durability: While this study used Digital Light Processing (DLP) printing with materials mimicking terracotta and stone, further research is needed to optimize materials for tactile clarity, durability, hygiene, and sustainability. Exploring bio-based or recycled materials could align inclusiveness projects with environmental responsibility goals within museum practices.

Despite these open issues, it is possible to conclude from this experience that the combination of high-resolution 3D surveying, additive manufacturing, and museology-aware targeted strategies can offer museums powerful tools to transform visitor engagement, reimagining cultural institutions as accessible, participatory, and equitable spaces for all. The tactile installations at Riccione demonstrate the potential of these technologies to enrich interpretive experiences, foster inclusion, and advance ethical commitments embedded within contemporary museology.

Future initiatives must build upon these results by prioritizing rigorous evaluation, enhancing technological integrations, and embedding inclusivity within institutional strategies. Only then can cultural heritage truly serve as a universal resource that empowers and connects all members of society, regardless of sensory or physical ability, advancing the shared goal of cultural democracy in practice rather than merely in principle.

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