

Photogrammetric 3D Digitisation of Bajuni and Pokomo Cultural Artefacts: A 65-Artefact Proof-of-Concept at Fort Jesus, Kenya

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Abstract

Digital preservation opens a practical route for protecting cultural objects that face material decay, shifting environmental conditions, limited accessibility, and the gradual erosion of contextual knowledge. This article documents a practice-oriented deployment of photogrammetric 3D digitisation carried out under the Leveraging Artificial Intelligence for the Preservation and Promotion of Coastal Cultural Heritage in Kenya (LAIPCH-K) project. Attention is placed on artefacts accessed via the National Museums of Kenya at Fort Jesus in Mombasa, with particular emphasis on how photographic capture, technology choices, local computing capacity, 3D reconstruction, quality checks, and metadata handling were brought into a single production workflow. The production log covers 65 cultural artefacts, and every object is supported by photographic documentation. For 44 artefacts, explicit image totals were recorded, amounting to 7,283 photographs. Per-object counts span 80 to 210 images, while the average is about 166 photographs per artefact. Work proceeded through image sorting and inspection, alignment of camera poses, Structure-from-Motion processing, dense Multi-View Stereo reconstruction, mesh creation, texture generation, post-processing cleanup, model refinement for use and dissemination, and export. To determine an appropriate toolchain, three candidate options were assessed, Meshy multi-view image-to-3D, Agisoft Metashape Professional, and 3DF Zephyr Lite. The comparison considered image constraints, licensing and cost, where processing would occur, and the limits imposed by available computing hardware. On this basis, 3DF Zephyr Lite was chosen for the locally executed photogrammetry pipeline. Overall, the study frames museum digitisation under resource constraints as a socio-technical undertaking. Successful production depended not only on capture and reconstruction steps, but also on the coordination of software, computing infrastructure, technical know-how, metadata practices, and systematic quality assurance. The resulting digital assets form an evidence-linked base for later digital-heritage work, including metadata expansion, search and retrieval, classification, multilingual access, and immersive forms of engagement. While the work establishes operational viability and reports production outputs, it does not provide an independent assessment of geometric accuracy or metrological performance.

Key Words: Bajuni; Pokomo; Cultural Heritage; Photogrammetry; 3D Digitisation; Fort Jesus; National Museums of Kenya; 3DF Zephyr Lite; Meshy; Agisoft Metashape; NVIDIA CUDA; Digital Heritage; Artificial Intelligence

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1. Introduction

The coastal region of Kenya hosts a wealth and diversity of material, architectural, linguistic and intangible cultural heritage. Beyond being repositories of physical artefacts, museum collections offer evidence that can be researched, taught and disseminated about histories, technologies, economies, belief systems and identities. Digital technologies thus present opportunities to enhance preservation, documentation, knowledge management and access while reducing the need for physical handling of fragile artefacts. Digital humanities research at the National Museums of Kenya (NMK)

underlines the potential of digital means for the preservation and dissemination of indigenous knowledge (Awuor et al., 2023).

The NMK, especially Fort Jesus in Mombasa, offer an appropriate institutional context for this study. Fort Jesus is part of the UNESCO World Heritage List and notable for historical value and evidence of cultural interaction in the Indian Ocean region. UNESCO designates the NMK amongst the major stakeholders for the conservation of this property. Research into the coastal archaeology collections at Fort Jesus has noted limitations of storage capacity, infrastructure and collections management, underlining the need for digital documentation and access strategies (Wanyama et al., 2023).

3D digitisation is a digital representation of geometry and surface appearance of an object. A 3D model enables viewing from multiple angles and can be used for documentation, conservation, education, research, digital exhibits and other public engagement activities. Photogrammetry is especially pertinent given resource constraints, offering a potentially more easily accessible means of image-based reconstruction as compared to dedicated 3D scanning equipment. Recent studies highlight its applicability to museum collections, underscoring the need for photographic acquisition, processing and quality control throughout the digitisation pipeline (Farella et al., 2022; Morita et al., 2022).

The Leveraging Artificial Intelligence for the Preservation and Promotion of Coastal Cultural Heritage in Kenya (LAIPCH-K) project was envisaged as part of a much larger digital heritage initiative that also encompasses oral histories and endangered languages. The long-term system design incorporates computer vision, natural language processing, intelligent retrieval and immersive technologies. This paper particularly addresses the artefact digitisation component of the LAIPCH-K project - the decisions, challenges and outcomes of making this part of the system a reality.

One important insight from the implementation phase was the inextricable link between software choice and photographic acquisition. The updated project log documents 65 cultural artefacts and around 7,283 source photographs, with acquisition documented from around 80 to 210 photographs per artefact. This corpus of photographic evidence underpins a vastly different workflow from one intended to synthesise a 3D model from one or a handful of reference images.

This study offers four key contributions. First, it documents a proof-of-concept photogrammetry workflow for 65 artefacts within a Kenyan cultural heritage setting. Second, it reflects on potential image-to-3D approaches in light of the photographic, financial and computational constraints of the project. Third, it documents the computing infrastructure, technical roles and quality control demands of practically local 3D reconstruction. Fourth, it illustrates how physical artefacts, photographic evidence, photogrammetric models and structured metadata can be linked to form an evidence base for future AI-supportive heritage services. This paper does not seek to position photogrammetry as a novel technology but documents its implementation within the context of a resource-limited East African cultural heritage setting. Recent academic work calls for such AI applications to be transparent, context-aware and sensitive to cultural particularities (Paolanti et al., 2026).

2. Background and Literature Review

2.1 Three-dimensional Digitisation in Cultural Heritage

Three-dimensional digitisation now sits at the centre of contemporary cultural-heritage documentation. By translating physical artefacts into digital assets, it becomes possible to inspect,

measure, analyse, preserve, and share objects without repeated handling or ongoing proximity to the originals. What began as work dominated by specialised laser scanning and structured-light setups has widened into a mixed technical landscape that includes photogrammetry, image-based reconstruction, optical sensing, LiDAR, structured light, and combined methods. Recent review work suggests that technology choice is increasingly guided by object scale and material qualities, target precision, the downstream use-case, and practical constraints such as equipment availability, processing capability, and budget, rather than a belief that any single technique is best in all settings (Li et al., 2025; Vannini et al., 2026).

Within museum collections, the relevance of 3D digitisation is not confined to producing visually convincing models. A digital surrogate becomes more useful when it keeps a traceable link to the physical item, the source images, accompanying description, processing decisions, and the conditions under which access is allowed. From this angle, acquisition belongs inside an information-management chain, not as a stand-alone modelling exercise. Archaeological and cultural-heritage literature makes the same point, placing emphasis on how digital information is organised, documented, and maintained across the full lifecycle of 3D heritage resources (Pavlidis et al., 2007; Guidi et al., 2015; Hess et al., 2016).

Such distinctions matter most for collections intended to support research and teaching. A 3D representation offers repeated access for students and researchers when objects are distant, fragile, or restricted from routine handling. Evidence from Acke et al. (2024) shows that structured workflows in 3D technologies can strengthen education and training in restoration contexts, with digital models functioning as reusable resources rather than one-off outputs. The practical value of 3D digitisation, then, rests less on the act of producing a model and more on establishing a reusable representation that can carry different applications over time. Purpose also sets the required fidelity. Models produced for web viewing can rely on different geometric and texture requirements than those intended for conservation measurement or scientific inspection. Put differently, specifications should be derived from intended use. Because requirements shift across use-cases, digitisation projects benefit from stating anticipated applications before committing to acquisition and processing choices (Remondino & Rizzi, 2010; Pavlidis et al., 2007). This becomes especially pressing in heritage institutions with limited resources, where spending on equipment and computing needs to be defensible against clearly defined preservation, research, teaching, and dissemination goals.

2.2 Photogrammetry and museum artefacts

Photogrammetry reconstructs three-dimensional form from overlapping two-dimensional photographs. In a standard Structure-from-Motion (SfM) plus Multi-View Stereo (MVS) pipeline, image features are detected and matched across views, camera poses are estimated, a sparse representation is produced, and dense reconstruction then yields a point cloud from which a surface mesh and texture are derived. As a result, the model remains anchored to an observable photographic record, rather than being produced only through visual guesswork (Pavlidis et al., 2007; Remondino & Rizzi, 2010; Farella et al., 2022).

Recent studies continue to confirm the usefulness of SfM–MVS for cultural-heritage objects, particularly where low-cost and widely available equipment is a priority. Morita et al. (2024), for instance, reported that pairing SfM–MVS with Reflectance Transformation Imaging can improve reconstruction when objects offer few distinctive surface features, while still keeping the workflow comparatively inexpensive. This is directly relevant to museum collections, because many artefacts

present monochrome, worn, repetitive, or otherwise feature-poor surfaces that strain standard matching algorithms.

Model quality therefore reflects the entire capture-to-processing chain, not merely the reconstruction software. Feature matching and subsequent geometry depend on image sharpness and exposure, depth of field, camera stability, the distribution of viewpoints, overlap, lighting conditions, and the presence of usable surface texture. Reflective materials, transparent elements, and texture-poor regions remain persistent obstacles. Applied findings indicate that such constraints are not always resolved through software adjustments, and may instead require changed illumination, added surface information, or supplementary sensing methods (Morita et al., 2024).

Two consequences follow for the present study. First, photographic capture needs to be treated as a technical part of the reconstruction method, not as preliminary documentation performed “before” the real work. Second, quality assurance should begin prior to processing, so that missing coverage, motion blur, uneven exposure, and problematic reflections are detected while the object remains available for re-photography. This approach reduces the risk that failure becomes visible only after substantial computation has already been invested. A further practical advantage is that photographs serve two functions at once. They act as archival documentation in their own right, and they supply the input from which the 3D model is generated. Keeping the original image set therefore maintains evidentiary continuity and allows future reprocessing as software and computational practices change.

2.3 AI image-to-3D generation versus photogrammetry

Rapid progress in generative artificial intelligence has opened an additional route to 3D production from images. AI-based image-to-3D techniques can infer geometry, texture, or novel viewpoints from a single image or a small set of images, lowering the capture burden in some scenarios. Heritage-focused studies already document these capabilities. Wang et al. (2025) examined single-image 3D reconstruction of painted pottery using diffusion and feed-forward approaches, and Zhang et al. (2025) reported single-image reconstruction of Buddhist sculptures using a domain-adaptive diffusion framework. Even so, generative 3D outputs should not be treated as equivalent to photogrammetry that is grounded in extensive observation. The underlying problems differ. Photogrammetry reconstructs geometry from multiple observations of the same physical object, while generative systems can infer or synthesise details that are not directly visible in the supplied imagery. In cultural heritage, that difference matters, because provenance, traceability, and documentary integrity are often core requirements.

AI can still be valuable as a complementary technique. It can support visualisation, synthesis of missing views, restoration-oriented research, rapid prototyping, and public-facing engagement. Stoean et al. (2024), for example, showed how AI-driven inpainting and 3D reconstruction can assist in producing digital representations of degraded artefacts. Yet any generated or inferred surface should remain distinguishable from geometry that is directly supported by photographic evidence.

In LAIPCH-K, this distinction guided the choice to preserve full multi-view photographic evidence and to rely on conventional photogrammetric reconstruction for the implemented artefact layer. AI-based methods remain pertinent for later stages, including image retrieval, classification, metadata enrichment, restoration visualisation, and multilingual discovery, but such applications should preserve provenance and keep observed evidence separate from machine-generated interpretation.

2.4 Digital heritage, Indigenous knowledge and governance

Digitisation, as a technical act, does not settle the governance issues that surround cultural heritage. Digital surrogates can raise questions around ownership, intellectual property, cultural sensitivity, community authority, access limits, and appropriate interpretation. These concerns become more pronounced when artefacts connect to living communities and to Indigenous or locally held knowledge.

The FAIR principles offer one framework for ensuring that digital resources are findable, accessible, interoperable, and reusable (Wilkinson et al., 2016). However, FAIR does not, by itself, decide who should control access to culturally sensitive content. That complementary dimension is addressed by the CARE Principles, which emphasise collective benefit, authority to control, responsibility, and ethics in Indigenous data governance (Carroll et al., 2020). International discussion on data governance reinforces the need for governance arrangements that fit local contexts. UNESCO's 2025 Data Governance Toolkit, produced with African and other international partners, places emphasis on inclusive and sustainable approaches that remain sensitive to context, and it includes Indigenous data governance along with capacity building in developing-country settings.

For the LAIPCH-K archive, the implication is straightforward: technical interoperability should not be read as an automatic justification for open public access. Different artefact records can require different access levels, depending on provenance, community expectations, intellectual-property agreements, and institutional permissions. Metadata, accordingly, should capture not only technical descriptors but also provenance, rights, restrictions, and the responsible authorities. With those elements in place, the archive can support discoverability while also enabling culturally responsible stewardship.

2.5 Research gap

Recent work has discussed photogrammetric pipelines, AI-driven image-to-3D reconstruction, and broader digital-heritage infrastructures. Yet, there remains little empirical record of what it takes for resource-limited cultural institutions in East Africa to run evidence-rich photogrammetric digitisation at scale, across sizeable artefact holdings, while still maintaining provenance and positioning the outputs for later AI-enabled services. Published studies tend to concentrate on discrete reconstruction methods, benchmarked technical performance, or narrowly defined use cases. Far less is said about the institutional arrangements and day-to-day operating requirements that make an evidence-linked workflow viable in an African heritage context with constrained staffing, budgets, and computing capacity. For coastal Kenya in particular, this omission matters: institutions there must constantly negotiate preservation and access aims against technical capability, available computational resources, cultural governance obligations, and community-sensitive approaches to managing information.

To respond to this implementation gap, the present study reports a proof-of-concept involving 65 artefacts at Fort Jesus, Kenya, carried out under the LAIPCH-K project. Instead of treating photogrammetry as a standalone technique, the analysis follows how photographic capture, choices around tools and processing approaches, local computing infrastructure, 3D reconstruction, quality control, metadata practices, and prospective AI uses can be assembled into a single, traceable digital-heritage workflow. The paper's main contribution is thus empirical and practice-oriented: it records, in operational terms, how evidence-rich photogrammetric digitisation can be put into routine practice

under the resource limits, institutional constraints, and governance conditions characteristic of a Kenyan cultural-heritage initiative.

3. Objectives of the Study

This study set out to design and record a workable, resource-aware workflow for converting selected Bajuni and Pokomo cultural artefacts into reusable 3D digital assets. Put plainly, the work focused on what is needed, in practice, to move from physical objects to shareable models under real project constraints. To that end, the study aimed to (1) document cultural artefacts using high-resolution, multi-angle photography appropriate for photogrammetric reconstruction, (2) review plausible image-to-3D pipelines and justify, in context, the choice of 3DF Zephyr Lite, (3) record the computing demands of processing multi-image datasets locally, (4) describe the step-by-step sequence used to turn photographic datasets into textured 3D models, (5) report the production status achieved in the 65-artefact proof of concept, and (6) clarify how the resulting digital assets can feed into the broader LAIPCH-K digital archive.

These objectives were intentionally oriented toward implementation. The study was not framed as a controlled benchmark comparing commercial photogrammetry packages, nor as an experimental test of AI-based reconstruction accuracy. Instead, it concentrated on documenting the choices made, the available infrastructure, and the end-to-end workflow required to make artefact digitisation operational within the project's specific resource and institutional setting.

4. Methodology

4.1 Research design

A practice-oriented case study was chosen and developed into a technical workflow design. Here, the unit of analysis was the artefact digitisation process itself, covering image capture, the selection of technologies, the supporting computing infrastructure, reconstruction procedures, quality assurance steps, and metadata production. Such a design fits the aims of the study, since the research question is concerned with how a museum digitisation workflow can be put into operation in situ, under institutional limitations and finite resources.

Empirical material was compiled from LAIPCH-K project documentation, technical logs, photographic deliverables, reconstruction records, and the documents provided for the software reviewed during the technology selection stage. The study remains descriptive rather than experimental in orientation. Accordingly, it did not include a controlled benchmark against laser scanning or structured light methods, did not rely on an independent geometric ground truth, and did not carry out a formal user evaluation or a statistical assessment of model accuracy.

The difference matters because strong visual appearance does not, by itself, establish geometric correctness. Current heritage research increasingly argues that 3D technologies should be chosen and checked against their intended use, while also stating openly the trade-offs involved, including geometric precision, texture quality, acquisition duration, and cost (Vannini et al., 2026).

4.2 Study setting and project context

The broader LAIPCH-K programme operates along the coast of Kenya, while the implementation described here concentrates on artefacts accessed via the National Museums of Kenya, specifically Fort Jesus in Mombasa. Digitisation sits as one strand within a wider effort that links

physical cultural heritage to digital preservation, including metadata practices, language resources, and later AI-supported discovery.

Working inside a museum setting shaped the methodological choices. Handling protocols required strict control, the physical objects needed to remain the main point of reference throughout, photographic material had to be kept as source evidence, and the overall workflow had to stay workable for routine use by local staff. For these reasons, the adopted approach placed weight on non-contact imaging, careful retention of the original visual record, and reconstruction steps that could be executed locally.

4.3 Updated artefact scope and proof-of-concept evidence strategy

After revision, the production scope covers 65 cultural artefacts. For 44 of these items, the project documentation lists explicit photograph counts, amounting to about 7,283 images in total, with per-artefact totals recorded between 80 and 210. The stated average of roughly 166 photographs applies only to the subset of 44 entries with recorded counts, and it should not be read as a precise mean across the full set of 65 artefacts.

For detailed visual presentation, five artefacts, Kiti cha ngozi, Kinu, Uteo, Mfiniko and Tahaliki, were chosen. Each example is shown as a pair: one source photograph alongside the corresponding reconstructed 3D output. This yields ten visual panels in all, whereas the production claim pertains to the larger collection of 65 artefacts. In effect, the reporting separates illustration from scale. Evidence for production resides in the complete 65-artefact record, while the five paired cases operate as a compact visual demonstration of the transformation from input imagery to reconstructed model.

4.4 Photography procedure and acquisition parameters

Photography was carried out by the NMK Multimedia Unit using high-resolution, multi-angle image capture. The acquisition plan aimed for substantial overlap between consecutive views so that shared features could support camera estimation and downstream reconstruction. Where appropriate, controlled lighting, a turntable, and measurement scales were included. Original image files were preserved as the primary photographic evidence.

Table 1. Documented and undocumented photography parameters

Parameter	Status in current project record
Camera make/model	Nikon Corporation / Nikon D7100
F-stop	f/8
Focal length	30mm
Image resolution	High-resolution acquisition;
Exposure time	1/125 sec.
Exposure bias	0 step
ISO speed	ISO-640
Object-to-camera distance	Not consistently recorded
Image overlap	Extensive overlap was intended; exact percentage not consistently recorded
Lighting	Controlled lighting used where appropriate
Turntable	Used where appropriate
Measurement/scale references	Incorporated where appropriate
Background	Not consistently documented
Original image files	Retained
Photograph count	Explicit counts available for 44 artefacts; 7,283 photographs
Photographs per recorded artefact	Approximately 80–210
Processing location	Local processing
Primary reconstruction software	3DF Zephyr Lite

Project records indicate the use of multi-angle capture, managed lighting, turntable-based acquisition when suitable, measurement scales, and extensive overlap. At the same time, key camera and lens details were not documented consistently across the full production dataset, including camera make and model, lens specification, focal length, aperture, shutter speed, ISO, object-to-camera distance, and the precise angular spacing between shots. These missing parameters are not reconstructed after the fact.

Table 1 summarizes what the documentation does report. Items not captured with consistency are marked explicitly as not recorded. This separation matters because the present work documents a production workflow as carried out in practice, not a controlled photogrammetry experiment in which acquisition variables were standardized in advance.

4.5 Technology selection and contextual decision framework

Technology selection was framed as a methodological choice, not as a head-to-head exercise aimed at declaring a single, generally best software platform. Criteria were anchored in two factors, namely the properties of the LAIPCH-K photographic dataset and the practical conditions under which the project was carried out. Five considerations guided the choice: (i) fit with a multi-image acquisition strategy; (ii) capacity to handle comparatively large image collections; (iii) where processing would occur and the extent of reliance on cloud services; (iv) licensing terms and affordability given the project budget; and (v) alignment with the local computing environment and the technical skills available. In line with established practice, the underlying premise was that 3D digitisation tools should be chosen with reference to the target use case, the nature of the input data, accuracy expectations, resource availability, and the institutional setting.

On this basis, three candidate approaches were reviewed: Meshy Multi-View, Agisoft Metashape Professional, and 3DF Zephyr Lite. Meshy was treated as an AI-driven image-to-3D option, while Metashape Professional and Zephyr Lite were treated as conventional Structure-from-Motion/Multi-View Stereo (SfM/MVS) photogrammetry workflows. This separation mattered in the present study because the LAIPCH-K acquisition protocol intentionally preserved dense, overlapping photographic coverage instead of depending on a small set of representative views. Meshy's Multi-View workflow thus followed a different reconstruction logic than the evidence-rich photogrammetric route adopted for the project. At present, its Multi-View mode supports up to four images per object, whereas the LAIPCH-K entries contained far larger sets, including explicitly documented counts as high as 210 photographs for single artefacts.

From a technical standpoint, Agisoft Metashape Professional aligned well with the project's multi-image reconstruction needs. The decision not to select it did not stem from any lack of capability, rather it reflected licensing and cost limits under which the work was conducted. At the time the manuscript was prepared, the commercial Professional edition was listed at USD 3,499. In a setting where resources were constrained, that figure constituted a substantial licensing burden.

Given these conditions, 3DF Zephyr Lite was selected. It offered a standard SfM/MVS pipeline consistent with the project's extensive image-capture strategy, enabled local processing, and could make effective use of the available NVIDIA CUDA-capable hardware. The selection therefore represented a context-sensitive trade-off across technical fit, affordability, the requirement for on-premises computation, and the expertise that could realistically be applied. This choice should not be read as a claim that Zephyr Lite outperforms the alternatives in general terms. Instead, it was the

option most closely aligned with the documented constraints and requirements of the LAIPCH-K implementation.

The selection process also points to a broader methodological principle. Under resource constraints in cultural-heritage digitisation, software purchasing should be driven by the properties of the evidentiary material and by the outputs sought. Before a reconstruction platform is chosen, parameters such as the number and type of source images, where processing will take place, the available computing capacity, licensing conditions, and the required level of reconstruction fidelity should be specified.

Table 2. Contextual comparison of candidate 3D reconstruction approaches for LAIPCH-K

Selection criterion	Meshy Multi-View	Agisoft Metashape Professional	3DF Zephyr Lite
Reconstruction paradigm	AI image-to-3D	SfM/MVS photogrammetry	SfM/MVS photogrammetry
Image strategy	Small multi-view set	Large multi-image workflow	Large multi-image workflow
Fit with LAIPCH-K acquisition	Limited	High	High
Processing	Cloud/service-based	Local	Local
Licensing context	Credits/plans	Higher-cost Professional licence	Lower-cost Lite licence
Local GPU relevance	Lower	High	High
Project decision	Not selected	Not selected	Selected
Primary reason	Image strategy differed from evidence-rich acquisition	Licensing cost	Technical fit + affordability + local processing

Note: Vendor prices and product limits are time-sensitive and may change. The comparison records the project's decision context rather than a permanent commercial ranking.

The criteria used for software selection were intentionally context-specific. No package was treated as inherently or universally “best”. Instead, the platform had to fit the project’s image-acquisition strategy while remaining compatible with the available budget, the local computing setup, and the technical competencies within the team. Such a situated rationale aligns with prior studies arguing that photogrammetry workflows in cultural heritage should be chosen with reference to available resources, practical workflow demands, processing behaviour, and the nature of the intended outputs (Rahaman & Champion, 2019; Vannini et al., 2026).

4.6 Computational infrastructure and the gaming-laptop decision

Table Handling large image sets imposes computational demands across multiple stages of the photogrammetric pipeline, including feature matching, camera pose estimation, dense reconstruction, mesh construction, and texture generation. At each point, workloads can be heavy, drawing on considerable CPU performance, substantial RAM, fast and sufficiently sized storage, and, where supported by the software, GPU acceleration.

For these reasons, the project procured a gaming-grade laptop equipped with an NVIDIA CUDA-capable GPU, rather than depending solely on standard office machines. The choice was not only infrastructural but also methodological: having capable hardware on-site made it possible to process photographic datasets locally and, in turn, limited reliance on external computing services. The computing requirements can be summarized as shown in Table 3.

Table 3: Computing requirements

Computing component	Role in workflow	Implementation implication
NVIDIA CUDA-capable GPU	Accelerates supported reconstruction operations	Dedicated NVIDIA GPU prioritized when acquiring the project laptop
High system RAM	Supports image sets, dense clouds and intermediate datasets	Higher memory reduces pressure during multi-image processing
SSD storage	Handles source images, cache files and project outputs	SSD treated as essential storage
Multi-core CPU	Supports CPU-intensive reconstruction stages	Gaming/workstation-class CPU preferred over basic office hardware
Sustained cooling/power	Maintains performance during extended processing	Gaming-class laptop supported sustained workloads

3Dflow’s technical documentation sets out the computational load associated with Zephyr and outlines recommended hardware configurations, including CUDA-capable acceleration. On that basis, the hardware selection aligned with the processing profile implied by the software.

Across the project records, the laptop make, model, and detailed component configuration were not logged in a uniform manner, and no attempt has been made to reconstruct or infer them post hoc. In later production phases, systematic capture of workstation specifications is warranted. At minimum, records should include CPU model, installed RAM, GPU and VRAM, SSD capacity, operating system, CUDA release, and the specific 3DF Zephyr version used for processing.

4.7 3D Reconstruction Workflow

Reconstruction proceeded as a set of ordered yet mutually dependent stages: organizing images and carrying out quality checks; aligning images and estimating camera parameters; generating a sparse reconstruction; producing a dense point cloud; building the mesh; creating textures; removing extraneous geometry and closing holes; reducing polygons where required; refining textures; and exporting derivative outputs.

Such staging reflects standard SfM/MVS practice, where reconstruction is better understood as a pipeline than as a single software action. Work in cultural-heritage photogrammetry similarly argues that end-model quality is shaped by choices and constraints distributed across acquisition, preprocessing, reconstruction, and post-processing steps (Farella et al., 2022).

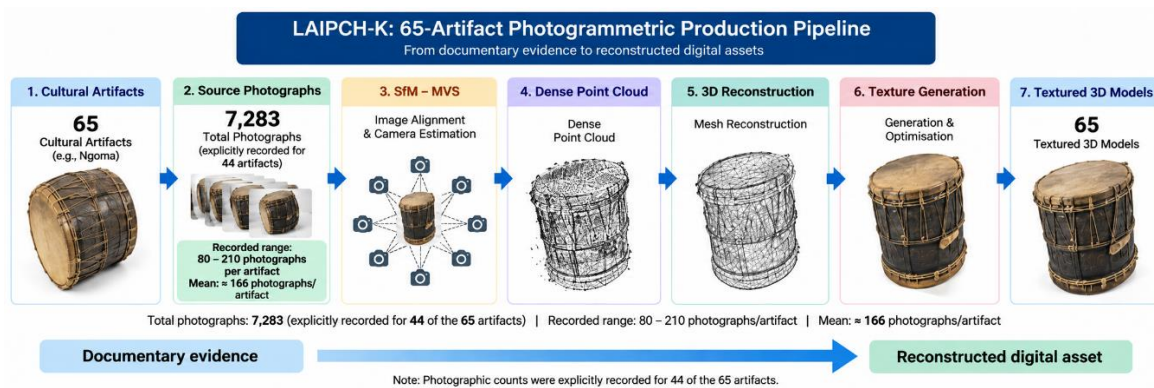
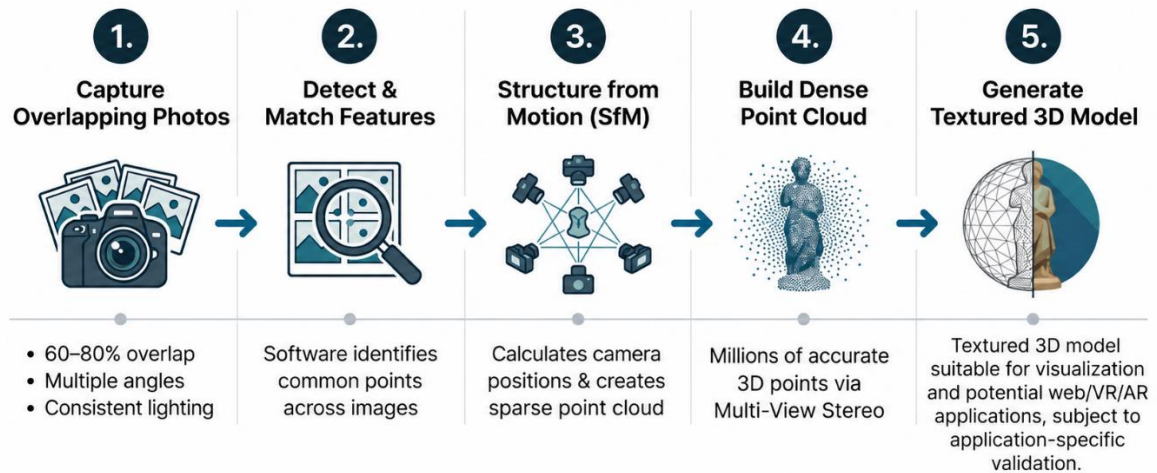


Figure 1. Updated LAIPCH-K production pipeline for the 65-artefact proof of concept. The photograph count is expressed as an approximate range because acquisition varied between artefacts.

Photogrammetry Workflow for Cultural Heritage



"Simplified overview. Real projects include quality checks and optimization at each stage."

Figure 2. Photogrammetry workflow, from the capture of overlapping photographs through feature matching and Structure-from-Motion to dense point-cloud production and a textured 3D result.

All reconstructions were run locally in 3DF Zephyr Lite. The workflow, as recorded, covered image organization and quality screening, camera alignment and estimation, sparse reconstruction, dense point-cloud generation, mesh construction, texture generation, model cleaning, optimization, and export. Yet the available production documentation does not reliably retain the full set of software-level parameters, including specific alignment configurations, dense-cloud settings, mesh-generation options, texture-resolution choices, polygon counts before and after optimization, and per-artefact processing times. Given this limitation, these parameters are not retroactively inferred or presented as though they had been controlled under standardized experimental conditions.

For future production phases, each reconstruction entry should document the 3DF Zephyr version, operating system, CPU, RAM, GPU and VRAM, CUDA version where relevant, image-alignment parameters, dense-reconstruction settings, mesh parameters, texture resolution, polygon counts pre- and post-optimization, processing time, and the exported file types. The overall workflow is condensed in Figure 1 and Figure 2.

4.8 Process visualization

Figure 2 sets out, in schematic form, how a physical artefact is translated into a digital representation. Work starts with a set of overlapping photographic views, then moves through feature correspondence and camera estimation, and only then proceeds to dense reconstruction, surface generation, and texture mapping. Ordering matters here, since the adequacy of the final model is constrained by the quality, coverage, and consistency of the information gathered during acquisition.

Within the same workflow, a boundary is drawn between primary evidence and subsequent outputs. Photographs function as the core documentary record. By contrast, the point cloud, mesh, and textured model are products derived through processing. Keeping these categories separate is not merely descriptive, it also supports later verification and, where necessary, reprocessing.

4.9 Division of technical responsibilities

Operationally, image capture and computational reconstruction were treated as distinct tasks. Artefact photography was carried out by the NMK Multimedia Unit, whereas the AI Analyst converted the resulting photographic datasets into 3D models using 3DF Zephyr Lite. With this separation, a traceable path is created that runs from the physical object to the photographic record and then to the reconstructed digital asset.

If the work is expanded in scale, this split in responsibilities should be stabilized through standard operating procedures, uniform file-naming conventions, processing logs, and version-controlled project documentation. Such a record makes it feasible to determine, for any given model, which individual, equipment configuration, software version, and processing step contributed to the end result.

4.10 Metadata and quality assurance

Metadata was handled as an accompanying strand of the workflow rather than an afterthought. The proposed metadata fields covered artefact identifier, artefact name, community association, provenance, material, dimensions, physical condition, description, capture date, photographer, equipment, processing software, and rights or access information.

Quality assurance was applied at two levels, the images and the models. At the image stage, checks focused on sharpness, exposure, overlap, reflections, motion blur, and unrecorded areas. During processing, attention shifted to camera alignment, disconnected cameras, incomplete surfaces, holes, unwanted background geometry, and texture artefacts.

This arrangement aligns with a general requirement in digital heritage practice: the resulting object should remain interpretable once the immediate modelling task is over. A 3D model that lacks provenance, a stable identifier, processing history, and access information offers limited long-term value in an institutional archive. End-to-end 3D imaging programmes therefore depend on structured documentation, quality control, and metadata that link acquisition to processing and, finally, to the published digital outputs (Hess et al., 2016; Guidi et al., 2015). Preserving the original images alongside structured metadata and derivative 3D assets thus supports a more durable digital collection.

For LAIPCH-K, the methodological point is that the 3D model should not be approached as a final endpoint. Instead, it is one connected layer within a broader evidence chain that includes the physical artefact, the source photographs, reconstructed geometry, metadata, processing records, and any later AI-derived information. With this structure in place, later applications are supported while the separation between documented evidence and computational interpretation is retained.

5. Results

5.1 Production output

The revised production record used in this manuscript covers 65 cultural artefacts, together with the documented photographic evidence associated with the collection. For all 65 artefacts, corresponding 3D model records were available, 52 records (80%) were designated as fully processed, while 13 (20%) were incomplete in one or more processing or quality-assurance fields. For the 44 artefacts with explicitly documented photographic records, the dataset comprised 7,283 photographs

in total, with per-artefact counts ranging from 80 to 210 images (mean ≈ 166). On this basis, the 65 models should be understood as a production collection rather than five isolated demonstrations. Table 4 summarizes the production output.

A useful proxy for productivity in the workflow is the relation between the count of source photographs and the number of models ultimately produced. Instead of generating stand-alone demonstration outputs, the project put in place a working pipeline in which photographic records were routinely converted into textured 3D assets that correspond to the documented objects. Such an orientation aligns with the current direction of cultural-heritage digitisation, where priority is given to repeatable procedures and interoperable, linked information, rather than to isolated digital surrogates.

The resulting outputs should be read as evidence that the pipeline functions in practice, not as a claim about measurement-grade accuracy. No independent geometric checking was conducted, for example through comparison with calibrated dimensions or a reference scan.

This separation between operational success and metrological performance has become increasingly consequential in heritage digitisation. Recent studies indicate that reconstructed 3D models can include artefacts introduced by the processing chain rather than reflecting properties of the original object. Errors can be introduced during image alignment, surface reconstruction, gap filling, texture creation, or later improvement steps, which makes expert review and a traceable processing history necessary even where the final model looks visually plausible (Sullini et.al., 2026).

Table 4. Updated production output of the LAIPCH-K 65-artefact proof of concept.

Indicator	Updated proof-of-concept status	Interpretation
Cultural artefacts documented	65	Current artefact set used for this revision
Source photographs	$\approx 7,283$	Explicitly recorded for 44 artefacts
Minimum photographs/artefact	≈ 80	Lowest recorded count
Maximum photographs/artefact	≈ 210	Highest recorded count
Textured 3D models	65	Completed reconstructed outputs reported for the current set
Representative visual pairs	5 artefacts / 10 panels	One source view plus one 3D output for each selected artefact
Primary reconstruction software	3DF Zephyr Lite	Conventional SfM/MVS photogrammetric workflow
Computing platform	Gaming-class laptop with NVIDIA CUDA-capable GPU	Acquired to support local reconstruction

5.2 Representative 3D reconstruction results

Figures 3 and 4 are offered as indicative outputs, not as a complete visual inventory. Across five examples, the figures show the source-to-model shift set out in the methodology.

By design, the selection is representative rather than comprehensive. From the 65-object production set, five artefacts were chosen to make the workflow legible without reproducing an extended and repetitive sequence of images. Each source/model pair should therefore be read as an illustrative instance of the production pipeline, not as a stand-alone experimental case.

What matters in this mode of presentation is the tie between primary evidence and its derivative. The source photograph defines what visual information is actually available to the reconstruction procedure. The 3D representation, in contrast, is an object-centred digital asset that

can be examined, edited, and deposited for later reuse. For that reason, the 3D model is best treated as an output derived from photographic evidence, not as a substitute for the photographs themselves.

As AI-based 3D reconstruction continues to mature, this evidentiary distinction becomes more consequential. Recent studies show that single-image AI systems can produce practical 3D representations of cultural objects, including painted ceramics and sculptural forms. At the same time, reported constraints remain, especially around recovering fine decorative features and inferring surfaces that are not visible in the input view (Wang et al., 2025; Zhang et al., 2025). In LAIPCH-K, the multi-view photographic set is therefore retained as the core evidentiary layer, regardless of any later incorporation of generative AI.

Representative Proof-of-Concept Outputs (1 of 2)

Each row pairs one source photograph (N) with its corresponding textured 3D output (3D).

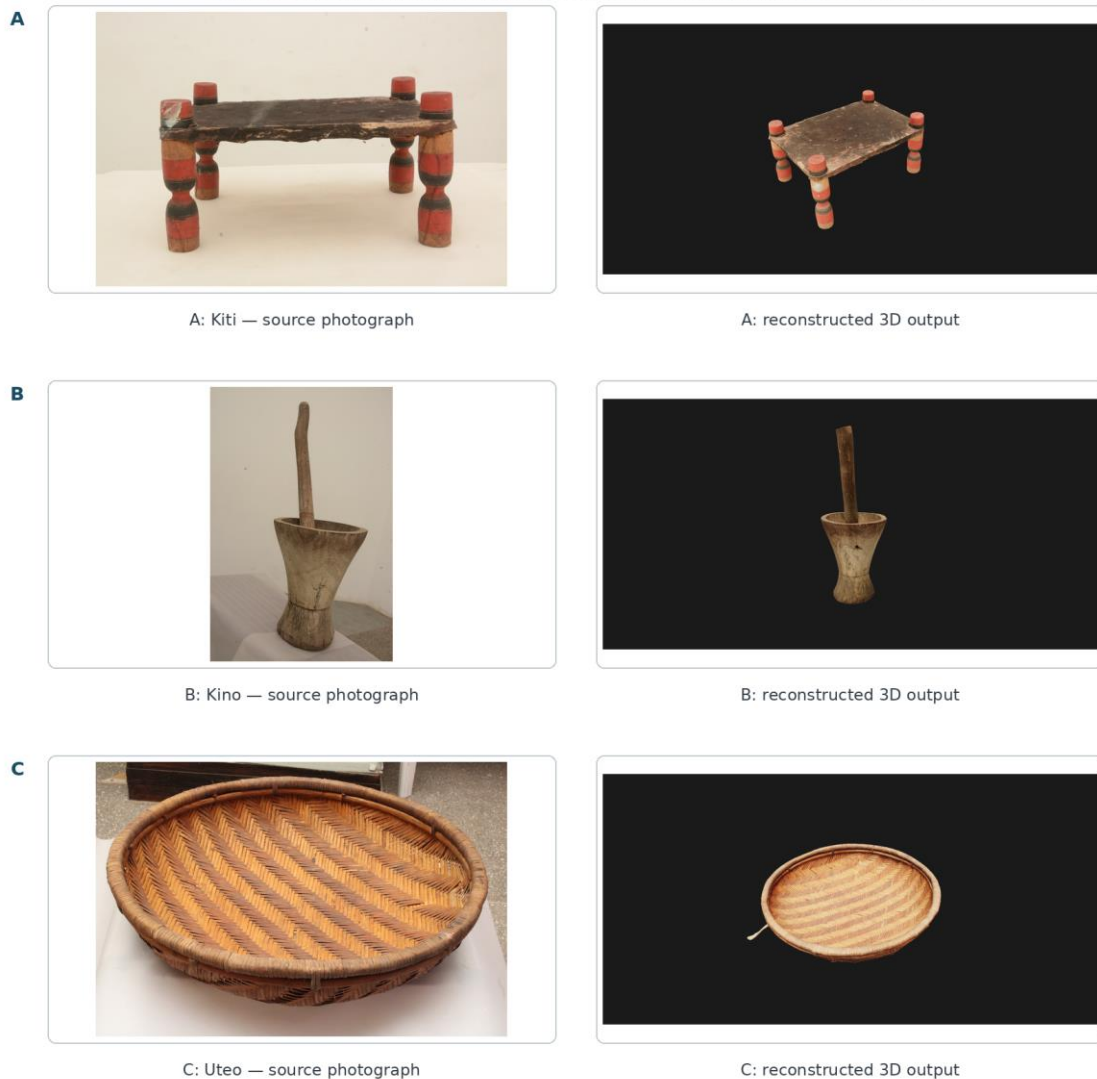


Figure 3. Representative proof-of-concept results (1 of 2): Kiti cha ngozi, Kinu and Uteo. Each artefact is shown as one source photograph (N) paired with its corresponding reconstructed textured 3D output (3D).

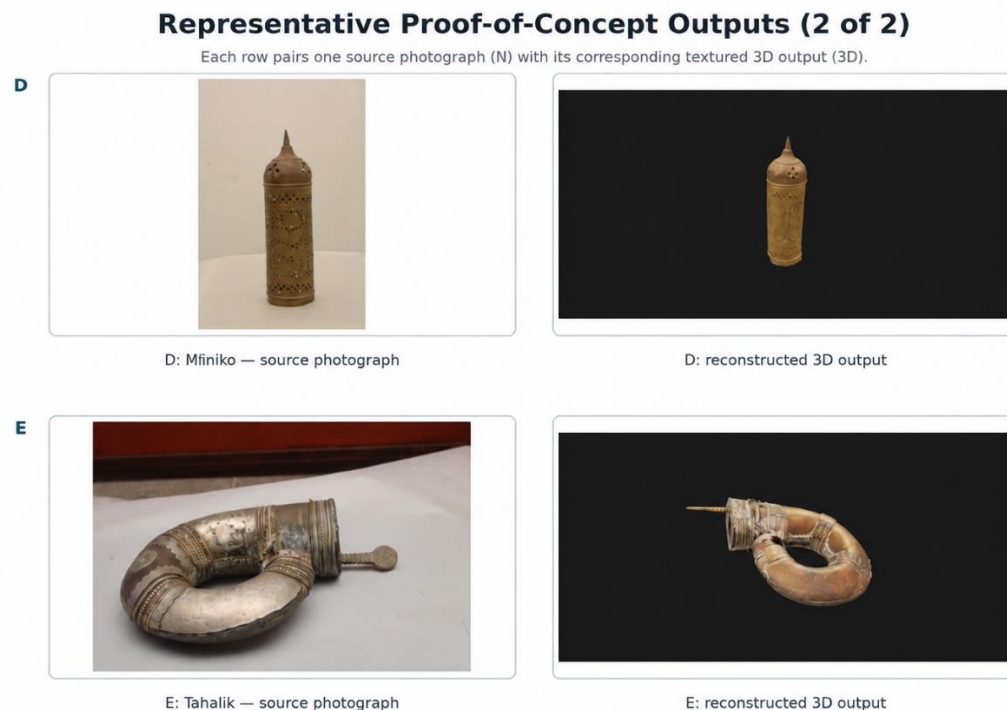


Figure 4. Representative proof-of-concept results (2 of 2): Mfiniko and Tahaliki. The five paired examples constitute ten visual panels selected from the 65-artefact production dataset.

5.3 Evidence structure for the complete collection

The complete evidentiary corpus is larger than the subset of models displayed in Figures 4 and 5. It includes the original photographs, the reconstructed models, the metadata records, and the processing documentation. To keep these elements navigable, they should be connected through a persistent artefact identifier, allowing a researcher to move from a model to its corresponding photographic basis and the associated descriptive record.

Accordingly, the production record treats photographs, reconstructed models, metadata, and processing information as linked parts of a single evidentiary system rather than as isolated files. Persistent artefact identifiers provide the practical means of maintaining these connections across the collection (Orzechowski et al., 2026).

Within the article, the project therefore relies on a compact production table plus representative visual examples, while the full collection is maintained as the underlying evidence base. Appendix Table A1 presents the complete production summary provided for this revision, including artefact identifiers, photographic documentation status, 3D-model records, metadata status, and processing status.

5.4 Operational observations

Implementation yielded several operational observations. First, acquisition and reconstruction need to be treated as one joined workflow. The number of images, their quality, and their distribution across views set the processing burden and shape which reconstruction software is appropriate. A tool

that performs well with small image sets is not necessarily suited to an approach grounded in extensive multi-view documentation.

Second, expanding image volume brings gains and overheads at the same time. More overlap can strengthen the evidentiary base for reconstruction, but it also raises demands for file organisation, storage and backup, image alignment, and processing time.

Third, image quality remains a basic requirement. Even advanced reconstruction systems remain sensitive to object characteristics, lighting, and acquisition conditions. Photogrammetry cannot recover information that was never captured in the first place. In practice, 3D digitisation therefore continues to require manual intervention, inspection, and expert quality control even as automation increases (Farella et al., 2022; Iakovaki et al., 2026).

Fourth, where reconstruction is carried out locally, computing infrastructure should be treated as part of the method. Large-scale processing is not merely an administrative IT concern, processor performance, memory, GPU capability, and storage capacity constrain what can realistically be reconstructed.

Finally, post-processing needs to be recognised as a substantive phase of digitisation. Before models are suitable for archiving or public release, unwanted geometry, holes, disconnected fragments, overly dense meshes, and texture defects often require correction (Farella et al., 2022).

6. Discussion

The results indicate that the central difficulty in museum photogrammetry is less about choosing a single software package and more about coordinating an interdependent socio-technical production system. Delivering the 65-artefact implementation depended on photographic acquisition practices, software, computing capacity, defined technical roles, metadata preparation, quality control, and file management. This aligns with prior work showing that heritage digitisation in practice is shaped by surface properties, acquisition conditions, equipment limits, processing demands, and the continuing need for expert intervention (Farella et al., 2022; Iakovaki et al., 2026).

Across the 65 artefacts, the implementation shows that the selected workflow could be applied throughout the project collection with available staff, equipment, and the local computing setup. In this context, scalability does not imply that one fixed parameter set can be applied unchanged to every object. It refers instead to the capacity to repeat the workflow reliably across a defined collection using locally available personnel, equipment, and computing resources.

6.1 Photogrammetry as an evidence-preserving approach

The findings strengthen the case for preserving original photographs alongside reconstructed models. Since models are generated from these images, maintaining the source imagery supports later reprocessing, verification, and the application of improved reconstruction methods. This is especially relevant as AI-based 3D reconstruction develops, because generated geometry can incorporate elements that are not directly observable in the source image (Wang et al., 2025; Zhang et al., 2025). For LAIPCH-K, the practical consequence is clear: AI-generated 3D assets should add to, not displace, the evidence-rich photogrammetric record.

6.2 Technology selection as a contextual decision

Selecting 3DF Zephyr Lite should be read as a methodological choice grounded in project conditions, not as a general claim of technical superiority. The software aligned with the multi-image

acquisition approach, the available local processing capacity, and licensing constraints. The case thus illustrates why reconstruction tools should be matched to evidence needs, institutional capacity, and intended outputs (Pavlidis et al., 2007; Remondino & Rizzi, 2010; Vannini et al., 2026).

6.3 Computing as research infrastructure

Purchasing a gaming-class laptop equipped with an NVIDIA GPU was a meaningful methodological step because it enabled local reconstruction. The computer did not serve only administrative functions, it became part of the production and processing environment.

This point extends to heritage institutions where high-performance computing access is constrained. Computing budgets need to account for GPU capability, RAM, SSD size, backup storage, power management, software licensing, and technical support. Cost-minimising approaches that disregard processing requirements can translate into delays or reduced image coverage.

Still, GPU acceleration does not replace careful acquisition. Hardware can speed computation, but it cannot reconstruct detail absent from the photographs. Practical studies in cultural-heritage digitisation continue to stress that manual inspection and expert intervention remain necessary despite increasing automation (Farella et al., 2022; Iakovaki et al., 2026).

6.4 Visual quality and geometric reliability

The results should not be taken as proof of metrological accuracy. Operational assessment focused on whether models were completed textured reconstructions, while the project did not report root-mean-square error, independent control-point measurements, completeness metrics, or comparisons against an authoritative reference scan.

This limitation matters because visual realism and geometric accuracy are not the same attribute. A model can look convincing yet contain local deformation, missing regions, or incorrect geometry. Recent research on photogrammetric heritage outputs cautions that reconstruction artefacts can be misread as genuine object features, which strengthens the case for traceable quality-control procedures across the processing pipeline (Farella et al., 2022; Sullini et al., 2026).

Later phases should therefore add independent validation, using calibrated reference measurements, control points, or high-accuracy scanning for a representative subset of artefacts. Such work would move the project beyond workflow feasibility toward quantifying reconstruction accuracy.

6.5 Metadata, provenance and digital sustainability

The results suggest that 3D digitisation should be paired with structured metadata that connects the physical artefact, photographs, model files, and processing history. Persistent identifiers and provenance records are especially important for long-term reuse, particularly when later AI-generated outputs might be appended to the collection. Managing data, metadata, and paradata together provides a practical basis for maintaining these links as the digital collection grows (Orzechowski et al., 2026; Hess et al., 2016; Guidi et al., 2015).

6.6 AI as an extension rather than replacement

The completed photogrammetric models also provide a base for later AI work, including image-based retrieval, visual similarity search, artefact classification, metadata suggestion, and multilingual discovery. AI outputs should, however, remain provenance-aware: generated descriptions,

classifications, and interpretations should preserve information about origin, confidence, and review status. In LAIPCH-K, AI is therefore positioned as complementary, extending the use of documented digital assets while leaving the underlying photographic and curatorial evidence intact. Human curatorial review and community input remain necessary parts of the information chain.

6.7 Layered architecture for LAIPCH-K

The implementation supports a proposed seven-layer architecture for a future LAIPCH-K digital heritage platform:

1. Layer 1 – Physical artefact and curatorial record
2. Layer 2 – Original photographic evidence
3. Layer 3 – Reconstructed 3D model
4. Layer 4 – Structured metadata and provenance
5. Layer 5 – Digital repository and access-control system
6. Layer 6 – AI services for enrichment, classification, retrieval and search
7. Layer 7 – Web, VR/AR and other public-engagement interfaces

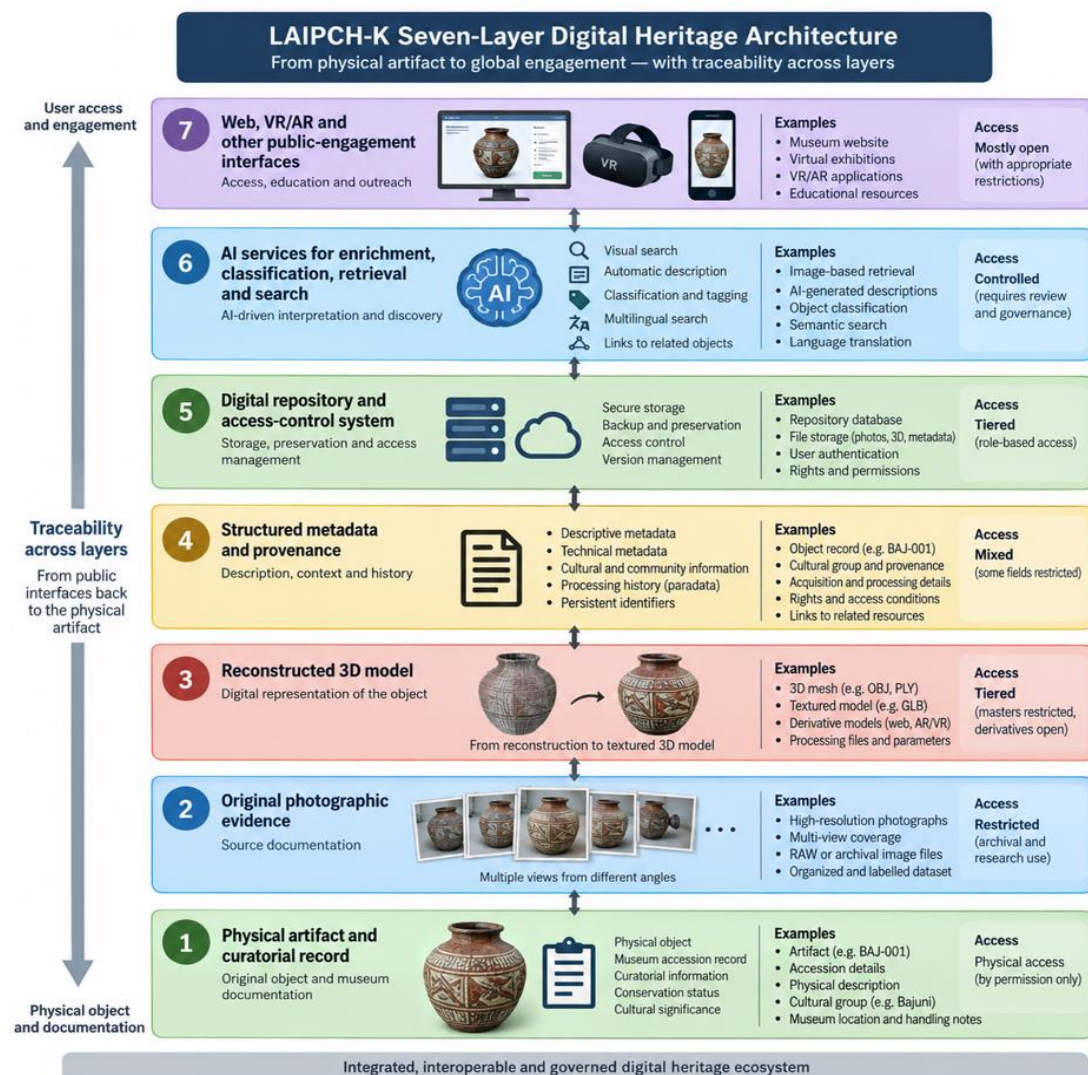


Figure 5. Proposed seven-layer LAIPCH-K digital heritage architecture.

Across the workflow, the core design commitment is traceability between layers. When a user encounters an AI-produced description or a visual-search match, they should, subject to permissions, be able to follow that result back through metadata and the 3D representation to the underlying photographs and the associated curatorial record.

Built into the same structure is the ability to apply different access rules at different tiers. High-resolution master photography can justifiably sit behind restrictions, whereas lighter 3D derivatives can be released for classroom or outreach contexts. In parallel, community-sensitive terms or culturally specific knowledge can require conditions that diverge from those governing baseline object metadata.

On this basis, the proposed architecture links technical interoperability with differentiated governance, rather than treating all forms of digital heritage information as if they should be opened in identical ways.

6.8 Contribution to Digital Heritage Practice in East Africa

The contribution of this study is not limited to producing a set of individual 3D models. Instead, it offers empirical grounding for how photogrammetric digitisation can be made workable inside an East African cultural-heritage institution operating under resource constraints. What the LAIPCH-K implementation makes clear is that successful digitisation rests on coordination, photographs as evidence, reconstruction software, locally available computing capacity, technical skills, metadata, quality checks, and institutional decision-making, not on obtaining a single advanced tool.

This implementation-oriented account matters particularly for heritage organisations in developing contexts, where expensive scanning systems, dedicated compute infrastructure, and specialised staff are not always available. The study presents a locally executable alternative that relies on extensive photographic capture and conventional SfM/MVS reconstruction, while keeping the original images as a continuing documentary substrate. From that foundation, institutions can then move, as capacity grows, toward more advanced repositories, AI-supported discovery functions, and immersive public-facing applications.

In that sense, Kenya is not merely the location of the work, it is integral to what the study contributes. The case illustrates how digital-heritage infrastructure can be built stepwise: first consolidating preservation of the physical artefact record and the photographic evidence, then adding traceable 3D reconstruction and structured metadata, and later extending into governed AI use and public engagement. Such staging can serve as an implementation reference for comparable institutions along the Kenyan coast and across East Africa, while acknowledging that local technologies, governance arrangements, and community expectations differ across collections.

7. Implications for Digital Heritage Practice

Several practical implications follow from the findings. First, choices about technology should start with acquisition design. It is the number and type of photographs that set the load placed on reconstruction software and hardware, so a project that intentionally collects extensive multi-view imagery needs a platform that can handle that evidence efficiently.

Second, compute requirements belong in budgets from the outset. When reconstruction is intended to be done locally, GPU-capable machines, substantial RAM, SSD storage, backup capacity, and reliable technical support function as methodological necessities.

Third, AI image-to-3D systems are best treated as complementary. They create clear opportunities for visualisation, fast prototyping, and reconstruction when imagery is sparse. At the same time, recent work points to persistent constraints, particularly around unseen geometry and the capture of fine surface detail.

Fourth, each artefact requires a persistent identifier that binds together the physical object, photographs, project files, the 3D model, metadata, processing history, and later derivatives.

Fifth, archival masters should be separated from dissemination assets. Original images and high-resolution models should be retained as masters, while optimised GLB, web, and other derivatives can be produced for distribution.

Sixth, metadata needs to hold cultural information as well as technical description. Standard technical fields should sit alongside community terminology, provenance, and explicit access conditions.

Seventh, outputs generated by AI should remain recognisably generated. Descriptions, classifications, translations, and interpretive statements should retain provenance, include confidence information, and record review status.

8. Limitations

The scope of the findings is shaped by several limitations. First, the work is an implementation study, not a controlled evaluation contrasting photogrammetry with laser scanning, structured-light methods, or AI-based image-to-3D generation.

Second, production records do not include independent measures of geometric accuracy, root-mean-square error, surface completeness, or systematic camera-calibration statistics. As a result, the outcomes demonstrate operational feasibility rather than metrological performance.

Third, the five artefact pairs shown in Figures 3 and 4 are illustrative examples drawn from the 65-artefact production set.

Fourth, photograph counts are not complete at the level of individual artefacts. Explicit totals are recorded for 44 artefacts, amounting to 7,283 photographs, while photographic documentation exists for all 65 artefacts. For that reason, the manuscript avoids asserting a single precise count for the full collection.

Fifth, prices and service limits for commercial software shift over time. The technology comparison therefore reflects the decision landscape at the time of implementation and should not be read as a permanent market assessment.

Sixth, the laptop used in the project was not consistently documented at the level of make and component specifications. Accordingly, the study reports functional requirements rather than inferred specifications.

Finally, the work does not include formal evaluation by museum visitors, students, researchers, or community members, and it does not quantify the performance of downstream AI applications.

9. Recommendations for the Next Phase

The next phase should move beyond an operational proof of concept toward a digital-heritage system that is technically reproducible at the institutional level. Achieving that shift will require standard acquisition protocols, complete processing logs, documented computing configurations, software-version records, persistent identifiers, and quantitative quality-control procedures.

1. Complete formal cataloguing of all 65 artefacts, assigning persistent identifiers and full metadata.
2. Standardise the technology-selection protocol, recording image volume, licensing, hardware requirements, processing time, output formats, and governance considerations.
3. Record full computing specifications, including CPU, RAM, GPU/VRAM, SSD capacity, operating system, CUDA version, and photogrammetry software version.
4. Add quantitative photogrammetric validation through scale bars, control points, independent measurements, and, where feasible, reference scanning.
5. Establish a formal quality-assurance protocol covering acquisition, alignment, dense reconstruction, meshing, texturing, and final inspection.
6. Preserve raw photographs and project files alongside the final models and derivative formats.
7. Apply persistent identifiers and version control to every artefact and all of its digital derivatives.
8. Put in place community review procedures for artefact names, cultural terminology, interpretations, language labels, and access restrictions.
9. Create future AI datasets only from approved records, ensuring museum and community permissions are secured before any model training or public release.
10. Assess AI-generated outputs systematically, including accuracy, bias, provenance, explainability, and cultural appropriateness.
11. Run user studies with students, researchers, museum professionals, visitors, and relevant community members to gauge educational and public-engagement value.
12. Develop a transferable standard operating procedure so the workflow can later be applied to other collections and museums along the Kenyan coast.

Taken together, these recommendations align with the direction now emerging in digital heritage practice, where progress depends increasingly on reproducibility, integrated metadata, quality assessment, and responsible deployment, rather than on simply producing a larger number of models. Recent research on integrated 3D heritage data systems and applied digitisation workflows similarly supports the centrality of these interconnected elements.

10. Conclusion

This study recorded and put into practice a field-ready photogrammetric workflow to digitise Bajuni and Pokomo cultural artefacts accessed via the National Museums of Kenya at Fort Jesus, Mombasa. Across the full chain, the workflow brought together photographic capture, checks on image quality, decisions about tool choice, on-site computing, Structure-from-Motion and Multi-View Stereo reconstruction, mesh building, texturing, quality review, plus metadata handling. In doing so, the study shows how photogrammetric digitisation can be run as an integrated institutional procedure in a resource-aware heritage setting, not treated as a stand-alone 3D software exercise.

The production record covers 65 cultural artefacts, and photographic documentation exists for every one of the 65 objects. For 44 artefacts, explicit photograph totals were recorded, adding up to 7,283 images, and counts per artefact ranged from about 80 to 210 photographs. Sixty-five 3D model records were also available, with 52 (80%) flagged as fully processed, while 13 (20%) remained unfinished in at least one processing or quality-review field. The five artefact pairs shown in the article offer representative visual evidence of the step from source imagery to model output, and the wider production record indicates the proof-of-concept scale.

Experience from technology selection indicates that reconstruction software is best chosen only after defining both the evidentiary requirements and the operating constraints. In the LAIPCH-K case, 3DF Zephyr Lite was adopted because its standard SfM/MVS pipeline aligned with a large multi-image photographic corpus, local execution needs, existing computing resources, and project cost limits. This choice should not be read as a claim of general technical dominance. Instead, it shows how practical factors, including image volume, where processing must occur, hardware capacity, licensing terms, and the expected deliverables, can steer methodological choices in technology.

A central limitation is that the study establishes operational viability, not metrological accuracy. Independent geometric ground truth was not available, and no reference scan, control-point checking, root-mean-square error evaluation, or formal measure of surface completeness was conducted. For that reason, the reconstructed models should not yet be treated as metrically authoritative representations. This constraint sets a clear interpretive boundary for the reported results and points directly to the next stage of technical confirmation.

The main contribution is an evidence-linked model for implementing digital heritage work under resource constraints in an East African setting. The work ties together the physical artefact, the original photographic evidence, the reconstructed 3D model, metadata, and processing information within a workflow that remains traceable. By showing that these elements can be coordinated through locally executable photogrammetric reconstruction, the study offers an incremental basis for later digital repositories, responsible AI-supported discovery, and broader digital-heritage uses. The Kenyan setting is integral to the contribution, because the study addresses the institutional, computational, and governance realities within which such infrastructure would need to be built.

The next phase of research should shift from proof of concept to an institutional practice that is validated and reproducible. Priority areas include quantitative geometric validation based on calibrated measurement and reference datasets, completion of persistent identifiers and metadata, formal quality-review procedures, long-term preservation of source imagery and processing records, and governance arrangements, at both community and institutional levels, for access and future AI use. Later work should also examine the educational, research, and public-engagement benefits of the digital assets, while assessing the accuracy, provenance, and cultural appropriateness of downstream AI.

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Data Availability Statement

The artefact image datasets and 3D models generated in the project are institutional and culturally sensitive research assets. Any public release should depend on NMK approval, relevant intellectual-property arrangements, and access protocols defined with the involved communities. Where permissions allow, metadata and selected derivative models might be shared through the planned digital archive. This article reports the updated project-level status used for the present revision.

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