

Preface

Cultural heritage carries the historical memory of nations, embodies the collective wisdom of human creativity, and bears witness to the long journey of exchanges, mutual learning, and shared growth among civilizations. To preserve these precious legacies from the erosion of time and to ensure that the achievements of civilization are not muted by geographical and temporal distances is a shared responsibility of our generation. Today, digital technologies are advancing at an unprecedented pace, profoundly reshaping the ways in which cultural heritage is protected, studied, interpreted, and disseminated. From high-precision data capture and intelligent monitoring to digital reconstruction and immersive presentation, technology is continually expanding the possibilities for the preservation and transmission of cultural heritage, while also opening new avenues for intercultural dialogue. The selection, curation, and dissemination of outstanding cases of cultural heritage digitalization not only offer a concentrated showcase of innovative practices from around the world, but also represent a significant step toward sharing outcomes and fostering exchanges and mutual learning among civilizations.

As a key platform for international exchange and cooperation in the digital domain, the World Internet Conference has consistently followed the innovative application and industrial transformation of digital technologies. In 2025, the Conference established the Specialized Committee on Cultural Heritage Digitalization, with a view to pooling global expertise, building international consensus, and identifying effective pathways through which digital technologies can facilitate intercultural exchange and mutual learning. In 2026, under the auspices of the Specialized Committee, the World Internet Conference launched a global call for cases on cultural heritage digitalization. Following multiple rounds of review by an international panel of experts, 45 cases with strong technological merit and significant demonstrative impact were selected from nearly 200 submissions, representing 13 countries and regions. These cases span a wide spectrum of areas, including heritage conservation, archaeology, presentation, and utilization, collectively illustrating how digital technologies are empowering the full chain of heritage protection, research, and dissemination.

This casebook is grounded in the rich practices of cultural heritage digitalization and offers a forward-looking perspective on the future of cultural transmission and technological innovation. It is our hope that this publication will facilitate technological exchange,

experience-sharing, and practical cooperation on a global scale, enabling more innovative outcomes to benefit cultural heritage conservation efforts across the world.

Looking ahead, the World Internet Conference Specialized Committee on Cultural Heritage Digitalization will continue to leverage its platform role, closely tracking new developments and emerging trends in the application of digital technologies to heritage preservation and transmission, while further deepening cooperation and exchange. We aim to foster a more fertile global environment for the continued vitality of cultural heritage in the digital age. We stand ready to join hands with partners around the world — to safeguard humanity's shared civilizational memory through the power of digital technologies, to advance mutual learning among civilizations through collaboration, and to enable cultural heritage, long steeped in history, to transcend time and space and reach a broader future, thereby instilling greater cultural depth into the endeavor of building a community with a shared future in cyberspace.

World Internet Conference

Specialized Committee on Cultural Heritage Digitalization

July 2026

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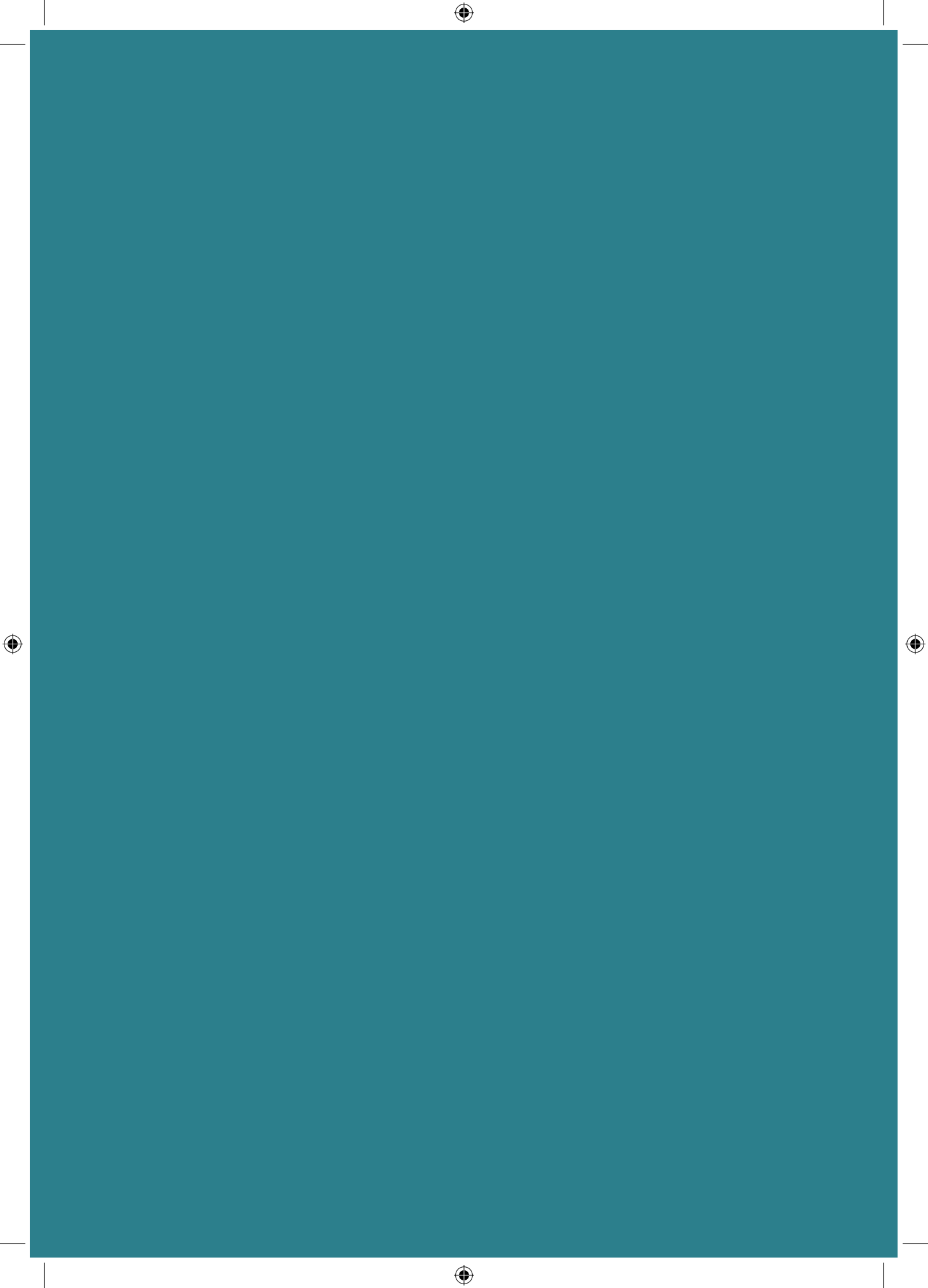
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Cultural Heritage Protection



001

Factum Foundation's Selene Photometric Stereo System

Applicant Institution

Factum Foundation for Digital Technology in Preservation

This case builds on over two decades of research by the Factum Foundation in the field of surface digitization of cultural heritage. In collaboration with the Factum Arte studio, the core technology was developed, and in partnership with the Bodleian Libraries at the University of Oxford, the ARCHiOx (Analysis and Recording of Cultural Heritage in Oxford) project was brought to fruition with the support of the Helen Hamlyn Trust. The project focuses on developing a high-precision system for capturing surface morphology and color information from low-relief and near-planar cultural objects. Breaking through the technical limitations of traditional two-dimensional imaging, the project employs photometric stereo vision as its core technology to uncover implicit historical information embedded in artifacts. At the same time, it has initiated the Selene Alliance to build an industry-wide collaborative network, promoting technological co-innovation and resource sharing among GLAM (Galleries, Libraries, Archives, and Museums) institutions worldwide, thereby forming a replicable high-precision digitization solution for cultural heritage.



Archiox copperplate

The Four-Dimensional Shortfall in the Digitization of Planar Cultural Objects

The global digitization of cultural heritage has been accelerating, yet the digitization of planar cultural objects has long remained confined to two-dimensional imaging. Manuscripts, prints, printing plates, and similar artifacts have largely been treated as two-dimensional objects for documentation purposes. Conventional photography can only capture color and macroscopic visual features, failing to reconstruct subtle surface relief. As a result, faint impressions, light incised decorations, erased or overwritten marks, and delicate hand-drawn details often escape detection, which in turn limits in-depth scholarly research and fine-grained conservation efforts.

Consequently, the sector faces four core shortfalls: insufficient sensitivity in capturing micro-level details, as conventional techniques cannot register surface variations at the micron level; a lack of multi-dimensional information, making it difficult to simultaneously acquire three-dimensional



Paper sheep globe

morphology, texture, and color data; restricted access to fragile and valuable artifacts, which limits physical examination by researchers; and the absence of unified industry standards, leading to inconsistencies in collection protocols and data formats across institutions. This project is designed precisely to address these structural deficiencies with a specialized technical solution.

The Five-Dimensional Breakthrough of Photometric Stereo Vision

The system builds a modular technical architecture based on the principles of photometric stereo vision, forming a closed-loop workflow encompassing non-contact acquisition, surface reconstruction, data integration, and results output. At the acquisition level, visible light and controlled directional light sources are employed, with zero physical contact throughout the process. At the reconstruction level, proprietary algorithms calculate surface normals to reconstruct three-dimensional morphology at micron-level resolution. At



Cuneiform Tablet

the processing level, lightweight operational software is provided, with GIS compatibility. At the output level, three types of professional data are generated — 32-bit depth maps, 16-bit RGB albedo maps, and normal maps — alongside exportable files for 3D printing replication.

The project adopts a collaborative industry-academia-research iterative development model. Core technology validation was completed on medieval manuscripts from the Bodleian Libraries at the University of Oxford, and has since been extended to artifacts of diverse materials, including copper plates, clay tablets, and mosaics. In parallel, the Selene Alliance was launched to bring together cultural heritage institutions worldwide and drive the harmonization of technical standards.

The project features five core innovations: ultra-high precision at a resolution of up to one million pixels per square inch, capable of capturing surface variations smaller than one-fifth the diameter of a human hair; multi-dimensional simultaneous acquisition, capturing three-dimensional morphology, texture, and color information in a single session; heritage-friendly operation with fully non-contact procedures; strong data interoperability, with outputs compatible with GIS and IIIF frameworks; and flexible deployment, enabled by a modular architecture suitable for both indoor and field settings.

Academic Breakthroughs and Global Impact

The deployment of the technology has facilitated multiple academic breakthroughs: the recovery of marginal annotations by the female scholar Eadburg in the eighth-century Selden Super 30 manuscript, confirming literacy among early medieval English women; and the identification of previously unknown engraved works attributed to the young William Blake on the reverse side of a copper printing plate from the James Basire workshop. High-precision digital archiving overcomes physical access barriers to rare and fragile artifacts, while the integrated IIIF viewer enables immersive three-dimensional browsing.



SelenePSS Portable



SelenePSS Studio

The system has been deployed at dozens of leading cultural heritage and academic institutions worldwide, including the British Museum, the Vatican Apostolic Library, the National Gallery of Art in Washington, and the Princeton University Library, and has been adapted to over ten material types, including paper, metal, stone, and ceramics. In 2026, it was awarded the European Heritage Award for Outstanding Contribution to Heritage. The Selene Alliance has taken the lead in promoting the development of ultra-high-precision cultural heritage data standards.

A Replicable and Lightweight Pathway

The system adopts standardized data output formats compatible with major cultural heritage digital platforms, allowing institutions to integrate without large-scale overhauls of existing workflows. Its modular hardware configuration supports on-demand selection, enabling small and medium-sized heritage institutions to build solutions tailored to their collection sizes. The alliance-based collaborative model, supported by unified training, technical assistance, and experience sharing, provides a transferable organizational practice paradigm for institutions lacking dedicated technical teams.

Future Plans and Collaborative Network Building

The project has laid out a three-stage development roadmap. The first stage focuses on optimizing core algorithms, introducing orthogonal polarization technology to enhance compatibility with reflective and translucent materials, and issuing unified technical specifications. The second stage advances implementation in three major areas: large-scale digitization projects, hybrid digital-physical exhibitions, and remote scholarly research, with the launch of a real-time interactive platform for ultra-high-precision three-dimensional data. The third stage prioritizes support for regions with limited digitization capabilities, working to elevate technical standards toward internationally recognized norms.

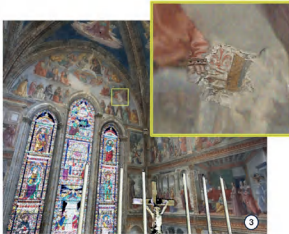
Technological innovation continues to extend to complex three-dimensional artifacts and natural science specimens, deepening the integration of AI-assisted analysis, WebXR visualization, and other emerging technologies, while also expanding into new application scenarios such as disaster monitoring for cultural heritage and digital twin collections. The project remains committed to the principle of open collaboration, advancing resource sharing and standard harmonization through its alliance mechanisms, and contributing to the collective building of a global digital cultural heritage infrastructure.



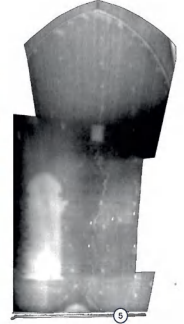
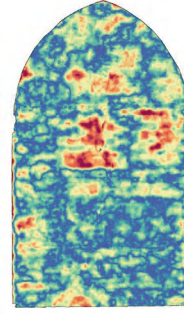
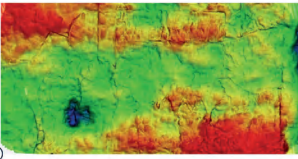
3D Atlas Archival and Streaming Infrastructure for Open Cultural Heritage Data

From big to small, placing multi-terabyte models on a global basemap, aligning high resolution and multispectral layers all in the same full resolution streaming system web-environment.

Below: The Basilica of Santa Maria Novella in Florence, Italy. We zoom from a global map (1), to see a full LiDAR scan of the church, inside and out (2).



The famous 15th century frescoes are beginning to crumble (3), revealing older paintings beneath! A structured light scan shows the complex organic geometry of the fresco surface, at sub-millimeter detail (4). Thermographic imaging shows the hidden structure of the walls, a door, a window, a crack running from floor to ceiling, all hidden behind the vibrant paintings (5).



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OpenHeritage3D.org: 3D Atlas Archival and Streaming Infrastructure for Open Cultural Heritage 3D Data

Applicant Institution

California Institute of Telecommunications and Technology (CALIT2)

Participating Institution

CyArk, University of California, Instituto Nacional de Antropología e Historia, Western Digital

This case builds on the long-term research accumulation of the Qualcomm Institute at the University of California, San Diego, in the field of 3D data acquisition and archiving of cultural heritage, and innovatively constructs a global 3D cultural heritage data archiving and streaming infrastructure centered on open standards.

Moving beyond the commercial approach of simply stacking platform features, the project directly addresses the core challenges of preserving, transmitting, and sharing large-scale 3D data. It has completed full-chain technological innovation and platform validation covering storage architecture, streaming transmission, spatial integration, and metadata specifications, resulting in a replicable and scalable solution for open cultural heritage 3D data infrastructure. This provides a benchmark paradigm for global digital cultural heritage preservation and open science practices.

The Challenge of Opening Up Large-Site Archives

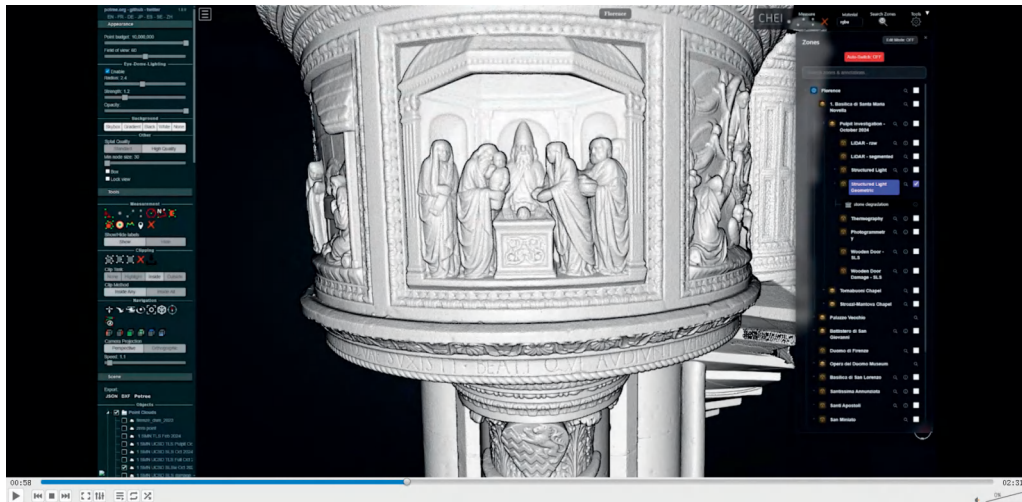
Over the past decade, the field of cultural heritage documentation has undergone profound transformation: terrestrial laser scanners, UAV-mounted sensors, and close-range photogrammetry systems can now routinely document archaeological sites and historic buildings at sub-centimeter accuracy, generating point clouds in the billions and high-fidelity 3D models. Yet a structural gap between data production capacity and data accessibility has prevented the vision of large-scale data sharing from being realized.

Currently, the field faces five major shortcomings: massive data volumes, with a single scan reaching hundreds of gigabytes and comprehensive datasets often reaching the terabyte scale, exceeding the storage and service capacity of traditional architectures; severe technical heterogeneity, with multiple instruments producing data in varying formats and coordinate reference systems, lacking unified standardization workflows; the absence of open transmission standards, with commercial platforms imposing file size limits and employing lossy compression that cannot support full-resolution point cloud streaming; data silos, lacking spatial integration under a georeferenced framework and cross-site comparative analysis capabilities; and insufficient sustainability, where data lack designated custodians after project completion, exposing them to substantial risk of loss. OpenHeritage3D.org was built precisely to address these structural deficiencies.

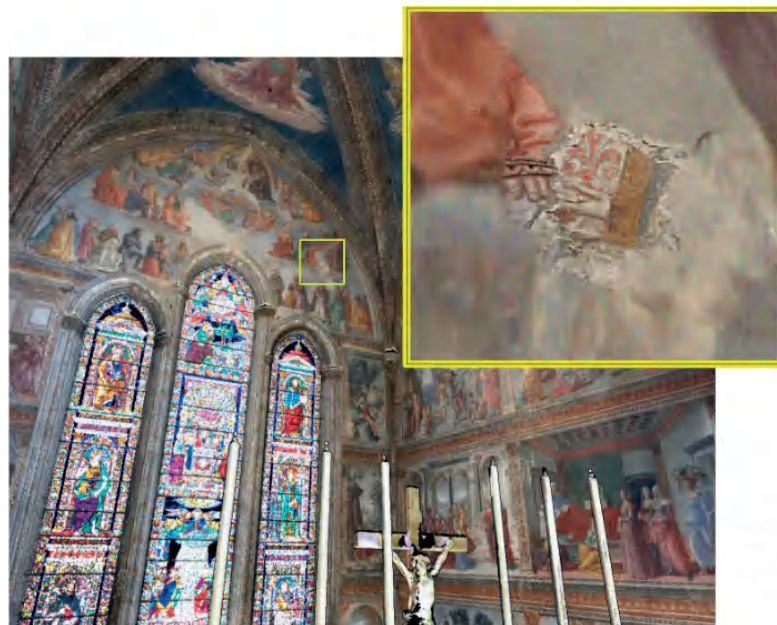
A Four-in-One Open Technical Architecture

The platform constructs a modular, open-source technology stack, pioneering a "four-in-one" architecture encompassing archival storage, streaming transmission, spatial integration, and open sharing. The storage layer preserves original point clouds in the lossless LAZ format, completely retaining coordinates, intensity, and echo metadata. The streaming layer, based on the Potree open-source renderer and employing octree data structures, enables level-of-detail streaming that allows users to interactively view billion-point clouds in a browser without downloading the full archive. The spatial integration layer employs the CesiumJS virtual globe engine to register site datasets to real geographic coordinates, supporting spatial contextualization at any scale, from continental to individual artifact levels. The metadata layer implements the FAIR principles, assigning persistent identifiers to ensure data citability and traceability.

The project follows a project-driven iterative development model, validating the core pipeline with site data from the Yucatán Peninsula in Mexico, and gradually introducing E57 format and coordinate transformation workflows for Italian historic buildings, integrating terrestrial LiDAR, close-range photogrammetry, and thermal infrared data. During the 2025 Southern California wildfires, the platform provided a scientific baseline for post-disaster damage assessment through pre-fire LiDAR archives, validating its change detection capabilities.



Structured light scan of the Brunelleschi pulpit in Santa Maria Novella. Multiple data layers are made available through the right-hand menu, enabling easy switching



Tornabuoni Chapel in Santa Maria Novella

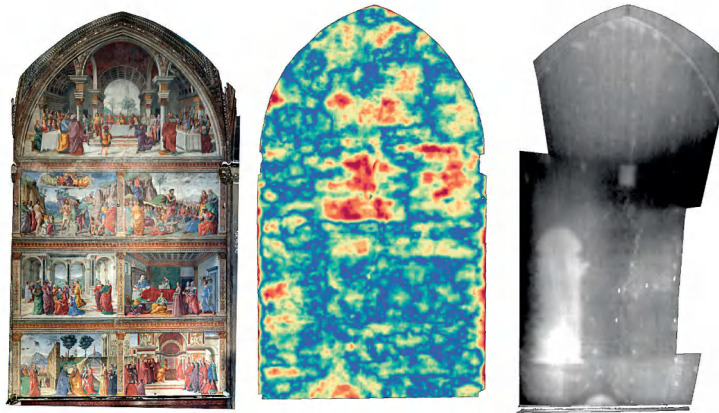
The project achieves breakthrough innovations across five dimensions: full-resolution open streaming, enabling for the first time interactive access to billion-point clouds in a standard browser without proprietary clients; multi-site spatial integration, bringing datasets from diverse global sources into a unified geospatial framework for cross-site comparison; scientifically faithful archiving, preserving raw data and metadata in their entirety to serve quantitative research rather than mere visualization; cross-sector applicability, having been extended to wildfire monitoring and infrastructure management; and open governance with mandatory open licensing, embodying genuine open access.



Basilica of Santa Maria Novella

From Academic Platform to Public Infrastructure

The platform has established the world's first open archiving and streaming system for full-resolution 3D cultural heritage data, enabling researchers, educators, and the public worldwide to access high-fidelity data without credentials, truly realizing the FAIR principles and the vision of open science. Post-disaster applications have validated the platform's direct social value in the field of public safety. The open infrastructure eliminates redundant development costs across institutions, and hardware donations have significantly alleviated long-term operational capital pressure.



East wall Tornabuoni Chapel, visible, planar deformation map, thermography

The platform has established formal partnerships with the Politecnico di Torino in Italy and the Cyprus University of Technology, building a transatlantic regional node network, and is actively engaged in international standard-setting through CIPA, submitting technical specifications to the OGC and ISO standards frameworks. The platform is actively expanding partnerships with Asian institutions to ensure that the network serves local research communities across all global regions.

A Replicable Open-Source Collaboration Paradigm

The core technology stack consists entirely of open-source components, requiring no proprietary software licenses. Hardware requirements for small and medium-scale deployments fall within the computing capacity of a typical university. The metadata templates are compatible with established standards such as Dublin Core and CIDOC-CRM, and can be directly adapted. The project-driven development model provides a transferable organizational practice paradigm for institutions lacking dedicated engineering teams.

From Regional Nodes to a Global Network

The project has laid out a three-stage development roadmap. The first stage focuses on establishing a federated architecture, deploying a regional node network, and formally submitting metadata standards to the OGC. The second stage develops WebXR visualization, research analysis APIs, and AI training data infrastructure, with the establishment of the first regional nodes. The third stage deploys nodes in Africa, South Asia, Southeast Asia, and Latin America, forming a globally distributed open 3D cultural heritage data network.

Technological innovation focuses on federated architecture interoperability, immersive visualization, large-scale quantitative analysis, and AI training dataset development. The platform continues to expand into emerging scenarios such as post-disaster and climate risk response, urban digital twin integration, and educational curriculum access. The project remains committed to open standards, ensuring that data value is not diminished by tool obsolescence; its strict open licensing policies guarantee that data remain genuinely accessible, providing a sustainably shared public resource for global cultural heritage preservation and digital humanities research.

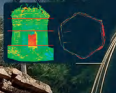
基于数字孪生框架的文化遗产全过程数字化保护实践

——佛光寺砖塔（后山区）砖塔修缮案例

Digital Conservation Practice of Cultural Heritage Throughout the Entire Process Based on a Digital Twin Framework
A Case Study of the Renovation of the Brick Pagoda (Houshan district) at Foguang Temple

Problem Focus & Status

现状勘查与长期风化(勘查-诊断-施工-评估的前期)

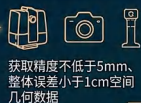


Full-Process Digital Twin Workflow

多源感知

数据融合

环境反馈



数字孪生

2020年6月

2024年6月

2025年10月

面向数字孪生, 实现多源数据融合与动态监测

决策支持

(Decision Support)



延年益寿而非改头换面, 最小干预原则
施工跟踪与现状复核, 适应性调整

Dynamic comparison between virtual repair and onsite construction

塔刹形制复原

2020年6月

2025年10月

现状勘查与长期风化
(勘查-诊断-施工-评估的前期)

Impact & Future

成效亮点



科学性修复



数据全过程可追溯, 可验证



能力建设现场培训



社会效益 & 传播



未来前景



国际间合作



国际间交流



经济与社会效益预期



多维价值释放



应用场景区展



同类型遗产推广、遗产教育



技术创新



由数据支撑向智能决策

Practice of Full-cycle Digital Protection for Cultural Heritage Based on a Digital Twin Framework: A Case Study of the Renovation of the Brick Pagoda (Houshan Area) at Foguang Temple

003

Applicant Institution

NHC, Tsinghua University

Participating Institution

Qingyuan (Beijing) Cultural Heritage Conservation and Development Center Co., Ltd., Shanxi Academy of Ancient Architecture, Painted Sculpture and Mural Conservation

This case takes three brick pagodas dating from the Northern Qi to the Jin and Song dynasties in the rear mountain area of Foguang Temple on Mount Wutai as the implementation subject. Led by the National Heritage Center of Tsinghua University, in collaboration with a multi-sector team integrating industry, academia, and research, this project represents a benchmark practice in China's brick and stone heritage conservation field, applying a digital twin framework throughout the entire project lifecycle.



Foguang Temple on Mount Wutai is hailed as "the foremost treasure of ancient Chinese architecture." However, for a long time, research and conservation resources have been heavily concentrated on the Eastern Main Hall, a Tang-dynasty timber structure, with research on brick pagodas accounting for less than 2% of total studies. The eight brick pagodas from the Northern Qi to the Jin and Song dynasties in the rear mountain area constitute core physical evidence for studying early Chinese brick pagoda construction techniques and typological evolution. These pagodas have long suffered from multiple forms of deterioration, including weathering, material degradation, and structural micro-deformation, making systematic long-term conservation and management considerably challenging. This predicament reflects deeper structural deficiencies in the field: experience-based decision-making lacks verifiability, as traditional on-site inspection and qualitative judgments cannot support precise intervention for complex deterioration; digitization is applied in a fragmented manner, with multi-source data failing to be effectively integrated to form a coherent knowledge system; technology and engineering remain disconnected, with digital outcomes largely used for preliminary surveying or display rather than carried through construction and evaluation phases; and the absence of whole-cycle tracking mechanisms means that continuous data baselines are lacking after project completion. This project is designed precisely to address these bottlenecks by establishing a whole-process digital conservation system.

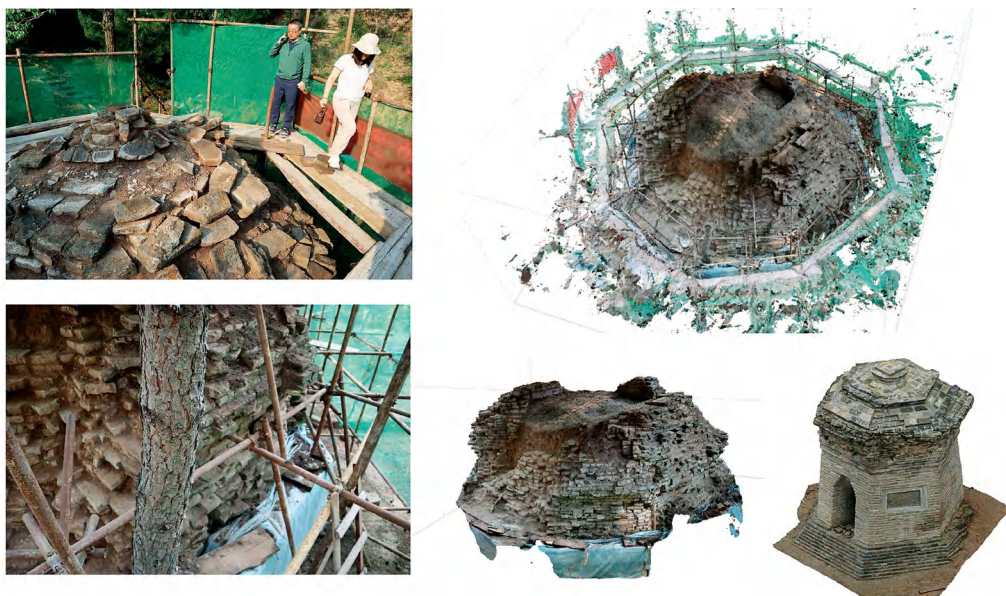
A Layered and Decoupled Digital Twin Technical Architecture

The project constructs a layered and decoupled digital twin technical architecture, forming a four-tier support system comprising the perception layer, fusion layer, twin layer, and application layer. The perception layer employs high-precision 3D laser scanning to capture millimeter-level spatial geometric data, combined with material microscopic analysis and environmental monitoring, covering full-dimensional information on spatial morphology, material composition, and environmental evolution. The fusion layer aligns and integrates multi-source data from geometry, materials, structure, and environment, achieving a deep mapping between qualitative expertise and quantitative data. The twin layer builds a full-element digital twin of the brick pagodas, carrying the whole-cycle dynamic mapping of heritage status, deterioration evolution, and intervention processes. The application layer delivers digital tools for all scenarios throughout surveying, decision-making, construction, and acceptance.

The project follows an engineering-driven iterative implementation pathway, progressing through four phases: survey, decision-making, construction, and acceptance. In the early phase, three rounds of high-precision scanning and multi-category material testing were conducted to establish a complete baseline of the heritage status. In the mid-phase, multi-source data were integrated for systematic assessment, defining a conservation strategy of "localized repair and minimal intervention." During the construction phase, periodic re-surveys enabled dynamic feedback and adjustment. At the completion phase, whole-cycle data archiving was completed, forming a digital asset library of approximately 11 TB.



Digital scanning



Digital tracking during construction

The project features four core innovations: whole-cycle closed-loop management, deploying digitization throughout the entire conservation process for the first time to achieve traceable, verifiable, and feedback-enabled control; deep integration of multi-source data, transforming geometric morphology, material deterioration, structural stability, and environmental evolution data combined with expert knowledge into a quantitative cognitive system; an innovative digital twin framework for brick and stone heritage that drives the industry's transition from experience-led to data-driven approaches; and strong transferability, with standardized workflows adaptable to various types of brick and stone structures.

Scientific Decision-Making and Engineering Effectiveness

The project has significantly enhanced the scientific rigor and precision of brick and stone heritage conservation. Key deterioration features can now be localized to centimeter-level accuracy, and the dynamic decision-making mechanism has effectively avoided the risks of one-off decision biases. The systematic conservation efforts have addressed the long-neglected brick pagoda heritage at Foguang Temple, strengthening the value representation of this World Heritage site. The approximately 11 TB digital asset library enables systematic digital preservation of heritage information, providing a foundation for long-term maintenance. On-site training conducted for conservation professionals nationwide has contributed to capacity-building at the grassroots level.

The whole-process digital management has substantially reduced the time required for solution validation, avoiding repeated site visits and redundant testing; precision interventions have minimized unnecessary material and labor inputs. The project outcomes provide a Chinese solution for brick and stone heritage conservation across Asia. The team has engaged in technical exchanges with international institutions such as ICCROM, and has initiated comparative research on Eastern and Western brick and stone heritage conservation with Cardiff University and KU Leuven.

工作成果

基于数字化成果的综合评估分析——大德方便和尚塔修缮效果评估

评估结论：经过数字化成果评估分析，塔顶修缮符合设计方案。塔顶碎石清理后，按原位置归安，符合文物保护原则。经持续观测，初步竣工后出现的不足及时发现并调整，塔顶后续并未出现后续病害问题，达到修缮效果。



2020年6月

基塔修缮前勘测记录，
塔顶被积土和杂草覆盖



2024年6月

清理塔顶积土后，将塔顶砖
按原位置码放，并编号记录



2024年8月

根据现存形制，对塔顶散砌
砖归安，剔除表层土，并抹
灰勾缝，并在其顶部铺一层砖，
以保护原有塔顶及塔心亭土。



2025年9月

因持续观测表明，东侧塔身
出现较为严重的雨水侵蚀，
因此补砌东侧缺失塔檐

Digital Tracking of Renovation Outcomes



before and after

- 1. Dade Pagada
- 2. Wugou Pagada
- 3. unnamed Pagada

Conservation effect comparison

A Replicable Whole-Process Methodology System

The comprehensive technical methodology package developed by the project can be directly transferred to similar brick and stone heritage conservation projects. The multi-disciplinary collaborative model offers a transferable practical paradigm for cross-sector cooperation. Data outputs are compatible with industry-standard formats and can interface with existing heritage conservation archive management systems, significantly reducing adaptation costs for implementing institutions. The whole-cycle data archiving provides a scientific baseline for future preventive conservation.

Technology Iteration and Scenario Expansion

The project has laid out a three-stage development roadmap. The first stage focuses on refining the technical system and standard specifications, introducing AI-based deterioration identification and risk prediction technologies to build predictive conservation models. The second stage promotes large-scale implementation of the technology, developing regional demonstration projects, establishing a cross-project data sharing platform, and creating digital training modules for practitioners. The third stage extends the approach to more brick and stone heritage types such as grottoes and city walls, building public digital dissemination platforms and deepening international cooperation and technology export.

Technological innovation continues to focus on dynamic updates of digital twins and intelligent risk early warning, extending to emerging scenarios such as preventive conservation and cultural-tourism integration. The project adheres throughout to the core principle of "data-supported expert decision-making," ensuring that technological applications ultimately serve the fundamental goal of heritage conservation.

BRIDGING INSTITUTIONS AND INNOVATION

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A network of excellence
uniting expertise, technology and passion
to preserve, enhance and share our heritage.



ARS NAUTICA

Marine Archaeology • Underwater Technologies •
Research • Training • Communication

arsnautica.org

Ars Nautica is an international reference
in underwater archaeology and the study,
protection and valorization of submerged
cultural heritage.



GNALICI SHIPWRECK
4th century BC
Central Adriatic Sea

1. UNDERWATER HERITAGE

Exploration. Research. Protection.

We investigate shipwrecks and submerged
sites to understand ancient maritime
routes, trade and civilizations.

- ① Archaeological surveys
- ② Site documentation
- ③ Context analysis
- ④ Heritage protection

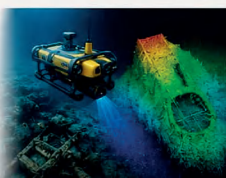


2. ADVANCED TECHNOLOGIES

Innovation for discovery.

We use state-of-the-art technologies
to detect, map and monitor underwater
cultural heritage.

- ① Multibeam echosounder
- ② Side scan sonar
- ③ ROV and AUV systems
- ④ Photogrammetry
- ⑤ GIS and data integration



3. DOCUMENTATION & 3D RECORDING

From data to knowledge.

High-resolution 3D models and digital
documentation make heritage accessible,
studied and preserved over time.

- ① Photogrammetry
- ② 3D modeling
- ③ Orthophotos & plans
- ④ HBIM & digital archives

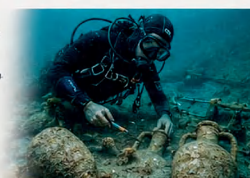


4. SCIENTIFIC DIVING

Human expertise under water.

Our professional divers operate
worldwide for archaeological
investigations and site monitoring.

- ① Scientific diving
- ② Excavation & recovery
- ③ In situ documentation
- ④ Conservation support



5. THE GNALICI SHIPWRECK PROJECT

A window on the ancient Mediterranean.

The Gnalici shipwreck, a unique 4th century BC
merchant vessel, is at the center of a long-term
international research project led by Ars Nautica.

- ① Excavations since 2007
- ② Hundreds of artefacts recovered
- ③ Photogrammetry
- ④ Conservation and study
- ⑤ Gagliana Grossa Virtual Museum

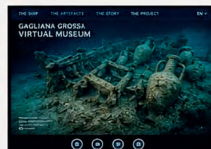


6. VIRTUAL MUSEUM & DIGITAL ACCESS

Sharing our heritage with the world.

The Gagliana Grossa Virtual Museum
offers an immersive experience of the
Gnalici shipwreck and ancient navigation.

- ① 3D interactive experience
- ② Artefacts and stories
- ③ Educational resources
- ④ Open to everyone, everywhere



7. TRAINING & KNOWLEDGE SHARING

Building skills. Inspiring the future.

We train archaeologists, students and
professionals through field schools,
courses and workshops.

- ① Field schools
- ② Training courses
- ③ Conferences & workshops
- ④ International collaboration



PRESERVE
our past



SHARE
our knowledge



INNOVATE
for the future



TOGETHER
we create value

Ars Nautica: connecting research,
technology and people to safeguard
the treasures of our seas.

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The "Gagliana Grossa" Virtual Museum

004

Applicant Institution

Institute for Maritime Heritage ARS NAUTICA

Participating Institution

University of Zadar (Department of Archaeology); University of Zagreb

This case centers on the "Galeana Grosa," a 16th-century merchant ship that sank off the eastern coast of the Adriatic Sea in 1583. Led by the Croatian Institute of Maritime Heritage, the project represents a benchmark initiative in maritime archaeology that integrates digital acquisition, scholarly research, and public exhibition.

The project consolidates over fifty years of underwater archaeological research to build a purely digital exhibition platform, connecting the entire workflow from underwater data capture, scientific analysis, and layered storytelling to public presentation. It makes this valuable underwater site permanently and freely accessible to a global audience, while pioneering a sustainable digital heritage operation model driven by a small non-governmental organization in collaboration with multiple partners.

The Challenges of Underwater Cultural Heritage Conservation

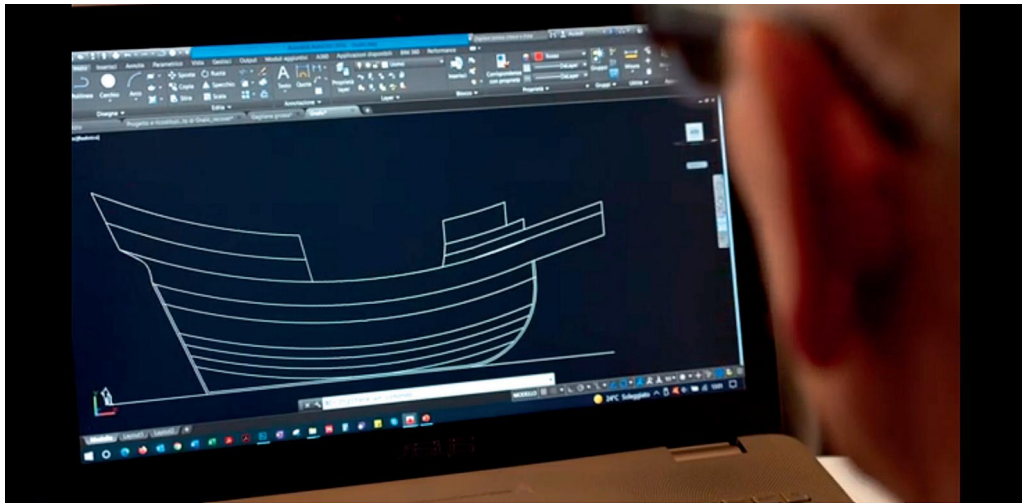
The "Galeana Grossa" is one of the most archaeologically valuable cargo shipwrecks from the late 16th-century Mediterranean, bearing witness to the trade networks that flourished between the Republic of Venice and the Ottoman Empire. However, underwater cultural heritage conservation faces five intertwined challenges: limited physical accessibility, as underwater sites are inherently inaccessible to the public; rapid site deterioration, with bioerosion, trawling, and climate change causing irreversible damage to remains; high technical barriers to implementation, as surveys require the integrated use of sonar, underwater photogrammetry, and 3D modeling, with diving operations severely constrained by oxygen supply and weather conditions; significant audience segmentation, ranging from specialized scholars to pre-school children, where a single narrative cannot meet all needs; and the difficulty of long-term operation and maintenance, where digital platforms often become inactive after project completion. This project systematically addresses each of these pain points.



Modular Technical Architecture and Layered Narrative Design

The project adopts a four-tier progressive modular technical architecture. The data acquisition layer completes multi-beam and side-scan sonar surveys of the entire site, along with high-precision underwater photogrammetry of the wreck itself and individual artifacts. The analysis and processing layer completes 3D reconstruction of the site and excavated objects based on photogrammetry,

conducts typological comparisons of artifacts against historical archives, and interfaces with the Adriatic Shipbuilding Database. The narrative and exhibition layer produces tiered content for different audiences based on the same core research data, linking the ship's history to broader themes of trans-Mediterranean population movements and cultural exchanges across eras. The public presentation layer launches a web-based virtual museum supporting 3D model browsing, complemented by a documentary series and multi-language interfaces.



The project has progressed in overlapping phases over more than a decade. Since 2010, annual international archaeological teams have conducted underwater operations, collaborating with humanities scholars from forty European countries on content curation, with the final platform development and ongoing updates supported by a professional technical team.

The project features four core innovations: balancing research and outreach through a unified data foundation and layered narrative design that simultaneously serves academic research and public science communication; connecting historical issues with contemporary themes, using the shipwreck as a point of entry to build a dialogue between historical research and current European migration discourse; a collaborative operational model led by a small NGO in partnership with universities, research institutions, international networks, and private enterprises, addressing the common problem of platform shutdown after single-funded project completion; and standardized operational workflows, establishing a systematic methodology for underwater photogrammetry that can be disseminated globally through university training programs.

Breaking Boundaries: The Convergence of Scholarly Rigor and Public Experience

The platform enables permanent, free, global access to the underwater site, breaking down the inherent barrier of physical accessibility. The tiered content design covers all age groups and diverse audience segments, ensuring both scholarly rigor and high-quality maritime cultural outreach. The connection between historical research and contemporary social issues expands the public value of

cultural heritage.

Digital exhibition avoids the substantial construction and operational costs of physical museums. The project's technical architecture and operational model are highly replicable: the underwater photogrammetry workflow has been applied at sites in multiple countries, and the entire model has been cited as a reference by Italy, France, Turkey, and other nations.

A Replicable Standardized Operational System

The standardized underwater photogrammetry workflow developed by the project can be directly transferred to digitization projects at various underwater sites. The layered narrative content production method offers a reference curatorial paradigm for segmented audience engagement. The multi-stakeholder collaborative operational model provides a replicable organizational pathway for small and medium-sized heritage institutions to achieve long-term sustainability of digital projects.

Three-Stage Global Expansion Roadmap

The project has laid out a three-stage development roadmap. The first stage (12 - 18 months) focuses on stabilizing platform operations, completing full multi-language interface coverage, and rolling out pilot educational modules for schools. The second stage (18 - 36 months) integrates extended reality (XR) and virtual reality (VR) technologies to create virtual diving experiences, develops AI-powered artifact identification tools, and adds two additional shipwreck sites along the coast. The third stage (36 - 60 months) replicates the project model at partner sites in multiple countries, participates in the development of international standards for underwater cultural heritage digitization, and extends the approach to more Mediterranean shipwrecks, ancient ports, and prehistoric underwater sites.

Technological innovation focuses on three directions: immersive experiences, AI-assisted research, and open data. The project adopts a diversified funding model combining national, EU, and private sources to ensure financial stability. International cooperation is deepened through the UNESCO framework to advance standard-setting, ultimately building a broader and more value-diverse digital conservation ecosystem for underwater cultural heritage.



A New Model for Digital Preservation and Utilization of Cultural Heritage Led by Suzhou "Ancient City Cell Anatomy Project"

005

Applicant Institution

Suzhou Gusu Ancient City Protection Committee (Suzhou Gusu Cultural Heritage Administration)

Participating Institution

Gusu Branch of Suzhou Natural Resources and Planning Bureau; Suzhou Mingcheng Protection Group Co., Ltd.; Suzhou Mingcheng Culture and Technology Co., Ltd.; Suzhou Urban Planning and Design Institute Co., Ltd.; Suzhou Surveying and Mapping Institute Co., Ltd.

This case is grounded in the overall conservation strategy of Suzhou as a National Historical and Cultural City. Taking the "Ancient City Cell Anatomy Project" as the core data hub, it coordinates and integrates multiple digital applications including the Ancient City Protection Information Platform, the Ancient City CIM Platform, the Smart Management Platform of Block 32, the Pingjiang Jiuxiang Metaverse, and the Shiquan Street digital mini-program, establishing an integrated closed-loop system encompassing "survey - protection - renewal - operation."



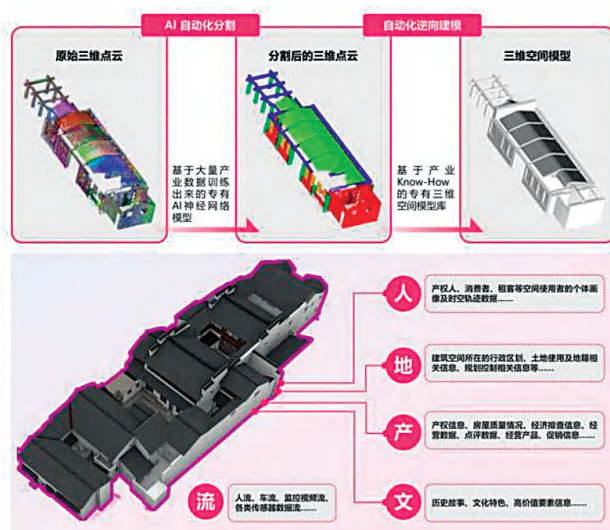
Focusing on ancient city buildings, immovable cultural heritage, and modern industrial heritage, the project develops tailored layered digital tools for three dimensions — government administration, neighborhood operation, and public experience — driving Suzhou's ancient city conservation from a traditional experience-based model to a comprehensively data-driven precision governance approach, forming a systemically complete, replicable, and scalable "Gusu Model."

The Real-World Challenges of Ancient City Conservation and the Pathway Forward

As one of China's first batch of National Historical and Cultural Cities, Suzhou has preserved its overall ancient city layout intact and serves as a core carrier of the Jiangnan cultural heritage. As urban development enters a new phase featuring the renewal of existing urban areas and precision governance, traditional conservation models face four major challenges: incomplete resource inventories, with heritage information scattered and fragmented, lacking a complete and traceable full-archive record; reactive conservation models, lacking the refined quantitative means to enable early deterioration identification; coarse data management, unable to effectively translate into urban renewal and industry-wide accessible application scenarios; and an incomplete system for active utilization, with a lack of coordination mechanisms between conservation and development. This project employs digital means to drive a fundamental transformation of the ancient city conservation model.

Construction of a Full-Chain Digital Technology System

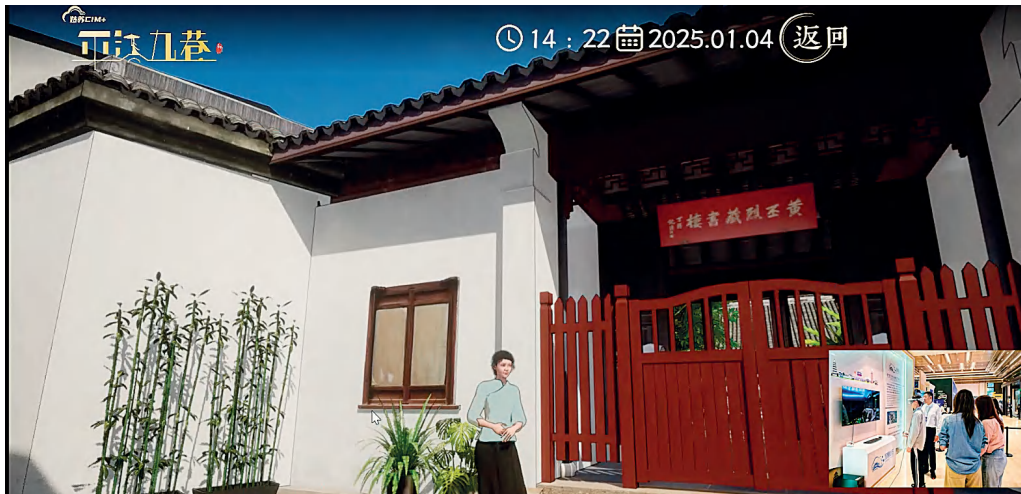
The project builds a comprehensive technical system encompassing "source survey - foundational platform - intelligent management - scenario deployment." Taking the "ancient city cell" as the core concept, it treats various buildings, courtyards, and historical elements as basic units for city-wide survey, employing 3D laser scanning and UAV oblique photogrammetry for high-precision acquisition, processing massive data through self-developed automated tools, and establishing a



Spatial database establishment for the digital twin platform

standardized ancient city resource database. Based on the Ancient City CIM Platform, it builds a city-wide digital twin foundation, achieving "one file per heritage object" digital mapping, supported by intelligent algorithms including height control, view corridor analysis, and compliance simulation for scientific decision-making. By layering IoT sensors, it enables 7 × 24-hour/24/7 dynamic monitoring and risk early warning of ancient building conditions.

The project follows a progressive approach of city-wide coordination and pilot implementation. It first



Pingjiang Jiuxiang Metaverse overview

conducts full-element surveys across the ancient city to build the foundational data base; then develops an integrated digital management platform to improve intelligent early warning and simulation capabilities; Subsequently, taking Block 32, Pingjiang Jiuxiang, and Shiquan Street as pilots to deploy applications scenarios including smart neighborhood operations and metaverse immersive tours, with full-city expansion following. After validation and iterative optimization, these practices are promoted citywide. The project features five breakthrough innovations: in technological innovation, it achieves automated point cloud data processing and AI-powered intelligent classification, bridging the gap between static archives



Standardized survey of the "Ancient City Cell Anatomy Project"

and dynamic sensing; in model innovation, it establishes a full-cycle closed loop, pioneering the capitalization of spatial data in historic districts; in institutional innovation, it establishes unified data collection and sharing mechanisms, breaking down cross-departmental barriers; in conceptual innovation, it optimizes urban renewal through digital means; and in governance innovation, it drives advanced the shift from reactive response to proactive prediction.

Layered Scenario Deployment and Multi-Dimensional Value Realization

The project has completed city-wide information collection across 31 historic neighborhoods and the Shantang area, cataloging over ten thousand heritage sites and newly identifying several thousand conservation elements, substantially improving the ancient city resource inventory. The intelligent monitoring system enables real-time early warnings for heritage risks and full-process construction supervision, greatly enhancing conservation precision. The platform has opened over 100 data service interfaces, with annual calls exceeding two million times, effectively empowering urban governance. Digital cultural tourism scenarios make ancient city culture tangible and perceptible, raising public awareness of cultural heritage.

Digital simulation and predictive analysis effectively mitigate construction risks and reduce resource



Dynamic early warning for heritage security



Visitor flow analysis

waste. Following the deployment of the Block 32 Smart Management Platform, commercial space occupancy rates increased significantly and investment attraction cycles are greatly shortened; Shiquan Street digital operations have doubled foot traffic, with steady growth in merchant revenue. The capitalization of spatial data unlocks the value of the ancient city's existing resources, providing new pathways for market-oriented operations of historic districts. The project has received multiple provincial and municipal awards and has been selected as a national-level exemplary case.

Standardized Systems and Replicable Pathways

The project's full-process standardized systems for digital survey, data management, and operations are adaptable to various types of historic cities and districts across China. The multi-stakeholder collaborative model involving government, enterprises, and research institutions effectively addresses challenges of resource fragmentation and single-actor approaches. The layered, categorized digital scenario operation system balances government administration, industrial development, and public experience, achieving a virtuous cycle of conservation, renewal, and revitalization.

From Gusu to the Nation: A Three-Phase Roadmap

The project has laid out a three-stage development roadmap. The first stage consolidates the data foundation, completing data supplementation for remaining neighborhoods, establishing regular update mechanisms, and iteratively upgrading intelligent search and risk warning functions. The second stage expands scenario deployment, upgrading metaverse immersive interactions and mini-program capabilities, and developing new scenarios including cultural tourism, science popularization, and low-carbon operations. The third stage advances nationwide expansion, consolidating standardized technical guidelines and operational specifications, building a cross-regional cooperation alliance, and establishing the "Suzhou Standard" for digital ancient city conservation.

The project adopts a diversified funding model combining government special guidance funds with private capital participation, broadening market-oriented revenue channels. It establishes data security tiered management, human-machine collaborative verification, and cross-departmental joint meeting mechanisms to systematically mitigate risks including data security, technical inaccuracies, and coordination challenges, while continuously optimizing the data-driven ancient city conservation and utilization model to support the living inheritance of Jiangnan cultural heritage and the high-quality sustainable development of the ancient city.

Tracing the Silk Road: Multimodal-empowered Intelligent Reintegration System for Ancient Document Fragments

Zheng Liu, Xuelong Li*, Mingyu Yang, Yu Weng*, Tieshan Zhang, Jun Wang, Ai Feng Chen, Tingting Liang

Key Laboratory of Intelligent Analysis and Security Governance for Ethnic Languages
Hainan Key Laboratory of Trusted Data Intelligence and Security Governance
Peking University, Turfanological Research Institute, Hangzhou Dianzi University, Haoyu World



Background & Motivation

The digital preservation of Dunhuang manuscripts faces severe bottlenecks: massive fragmentation and extreme physical degradation across thousands of globally scattered relics.

Traditional computer-aided methods relying on single independent features (like geometric contours) often collapse under complex weathering and high-dimensional uncertainty noise.

To realize the cross-border "digital reunion" of this scattered heritage, we propose DuelGraphNet—an interactive multimodal graph framework. Inspired by human cognitive processes, it dynamically fuses heterogeneous visual and semantic clues for high-precision automated reassembly.

The Bottleneck: "Embed-then-Compare"

Traditional metric learning models (e.g., Siamese networks) extract features in isolation before any comparison occurs.

This early decoupling forces models to learn broad, generic representations, severely suppressing critical local contextual clues that require interactive context to be detected (e.g., continuous brushstrokes and text semantics).

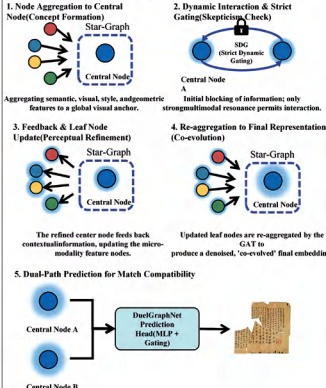
Consequently, this paradigm leads to unacceptably high false-negative rates. Nearly 30% of true associations are discarded in the initial retrieval stage due to severe physical weathering at the fracture edges, limiting their potential as reliable hypothesis generators.

Methodology: DuelGraphNet Framework

We abandon the traditional paradigm and construct a Coupled Star-Graph topology enabling early dynamic fusion of heterogeneous modalities (Semantic, Visual, Style, and Geometric).

Strict Dynamic Gating (SDG): Initialized with a negative bias, it conservatively suppresses background noise. It acts as an intrinsic manifold regularizer, establishing associations only upon strong multimodal resonance.

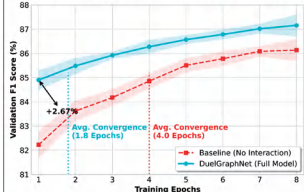
Detailed Architecture of DuelGraphNet



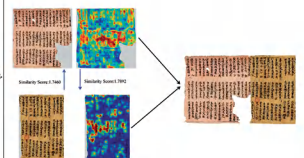
Breakthrough Results & Efficiency

Under a zero-shot sim-to-real protocol on the AFRB benchmark, DuelGraphNet achieves an unprecedented **82.94% F1 Score** and **90.07% Recall**, breaking the traditional performance trade-off.

Optimization Dynamics: Warm Start & Fast Convergence



Caption: SDG enables a strong warm start (+2.67% F1 gain) and ultra-fast convergence in just 1.8 epochs.



Caption: Spatial attribution heatmaps reveal "cognitive resonance". The model dynamically anchors on continuous text semantics and brushstroke styles when physical boundaries are heavily weathered.

Broader Impacts

Neuro-Symbolic Pipeline for Real-World Deployment:

By positioning the neural network as a high-recall hypothesis generator, we integrate a deterministic geometric verifier (FusionVerifier) as a post-processing filter. This mechanism successfully eliminates geometrically incompatible candidates while preserving true matches, safely boosting the overall F1 score to 85.33% (+4.41% precision gain). It establishes a highly reliable "Machine Recommend → Expert Verify" workflow for cultural heritage preservation.

Cross-Disciplinary Generalization (AI for Science):

The "Coupled Star-Graph" topology proves to be a universal computational backbone for discovering non-Euclidean "structural complementarity". Beyond ancient manuscripts, it achieves a remarkable 98.37% F1 score in semantics-free visual puzzle reassembly (ImageNet). Furthermore, it successfully captures implicit biochemical affinities in strictly Zero-Shot and Cold-start Drug-Target Interaction (DTI) tasks, demonstrating robust generalization capabilities in micro-biochemical domains.

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Tracing the Silk Road: Multimodal-empowered Intelligent Reintegration System for Ancient Document Fragments

Applicant Institution

Minzu University of China – Key Laboratory of Ethnic Language Intelligent Analysis and Security Governance (Ministry of Education)

Participating Institution

Peking University; Academy of Turfanology; Beijing Haoyu World Surveying And Mapping Developing Co., Limited; Hangzhou Dianzi University; Hainan International College, Minzu University of China

This case addresses the major national strategic demand for cultural digitization, focusing on the rescue preservation and living inheritance of world-class cultural heritage — ancient manuscripts and documents. Targeting the core bottlenecks in the digitization of ancient texts — "massive fragments, severe degradation, and extreme difficulty in reassembly" — the project innovatively employs AI multi-modal models and computer vision technologies to build a high-precision automated reassembly technical system tailored for complex degradation scenarios.

The project builds from the ground up a multi-modal perception model adapted to the unique characteristics of ancient manuscripts, decoupling fragment information into four complementary dimensions: edge geometry, calligraphic style, visual foundation, and contextual semantics. It establishes a human-machine collaborative workflow of "machine preliminary screening within seconds — expert one-click validation," reducing comparisons among tens of thousands of fragment images to a high-dimensional spatial retrieval task completed in seconds. In cross-domain testing on real degraded manuscript fragments, the system achieved over 90% retrieval recall rate and comprehensive matching accuracy, providing an intelligent solution with independent intellectual property for the creative transformation and innovative development of China's outstanding traditional culture.

The Industry-Wide Challenge of Manuscript Reassembly

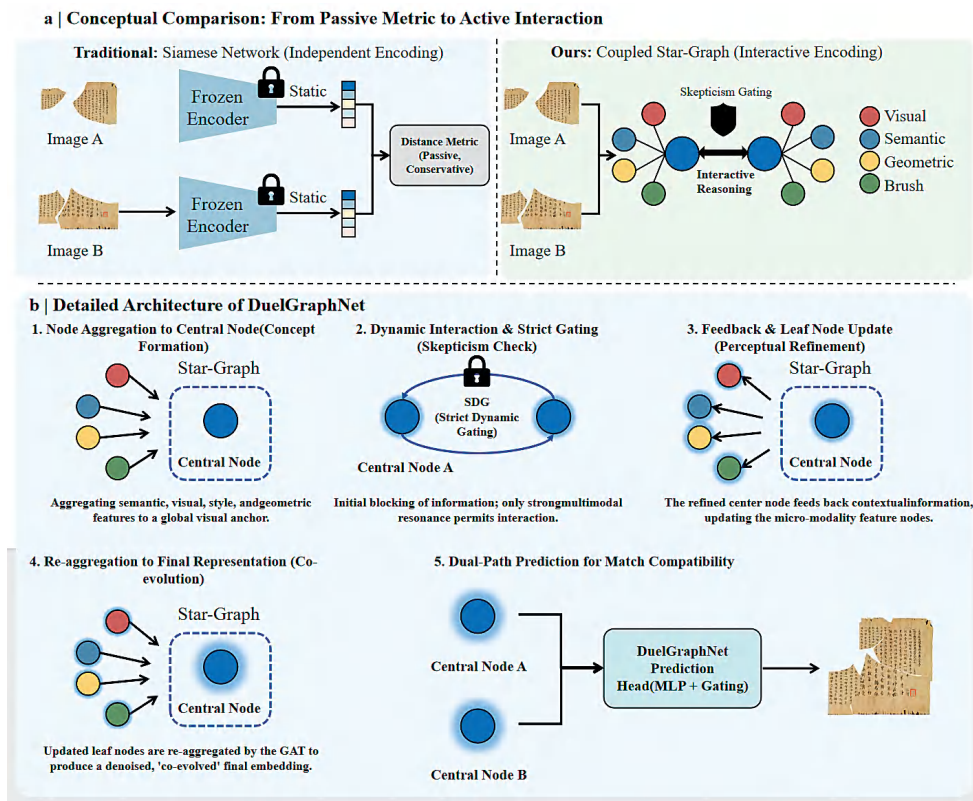
Silk Road manuscripts represent a precious cultural heritage carrying the Chinese civilization. Over millennia of natural erosion and human damage, tens of thousands of document fragments are scattered across the globe.

Currently, the digital preservation of ancient manuscripts faces three major shortcomings: first, the bottleneck of manual reassembly efficiency — traditional restoration relies heavily on the memory and visual comparison of experts, making the process of matching vast numbers of fragments of varying shapes and incomplete texts akin to "finding a needle in a haystack," resulting in exceedingly slow progress; second, insufficient depth in digital applications — existing work largely remains at the superficial stage of image archiving, without fully exploiting the complete semantics and multi-dimensional cultural attributes embedded in the fragments; and third, significant deficiencies in technical adaptability — existing computer-assisted reassembly techniques rely heavily on physical contours or surface texture features, which fail dramatically in complex degradation scenarios involving fragile edges, insect damage, and mold.

This project focuses on the core challenge of high-precision, automated reassembly of ancient manuscript fragments in complex degradation scenarios, dedicated to transforming massive, heterogeneous, unstructured fragmentary remains into structurally complete, readable, and interpretable digital cultural assets.

Multi-Modal Perception and Intelligent Reassembly Technology System

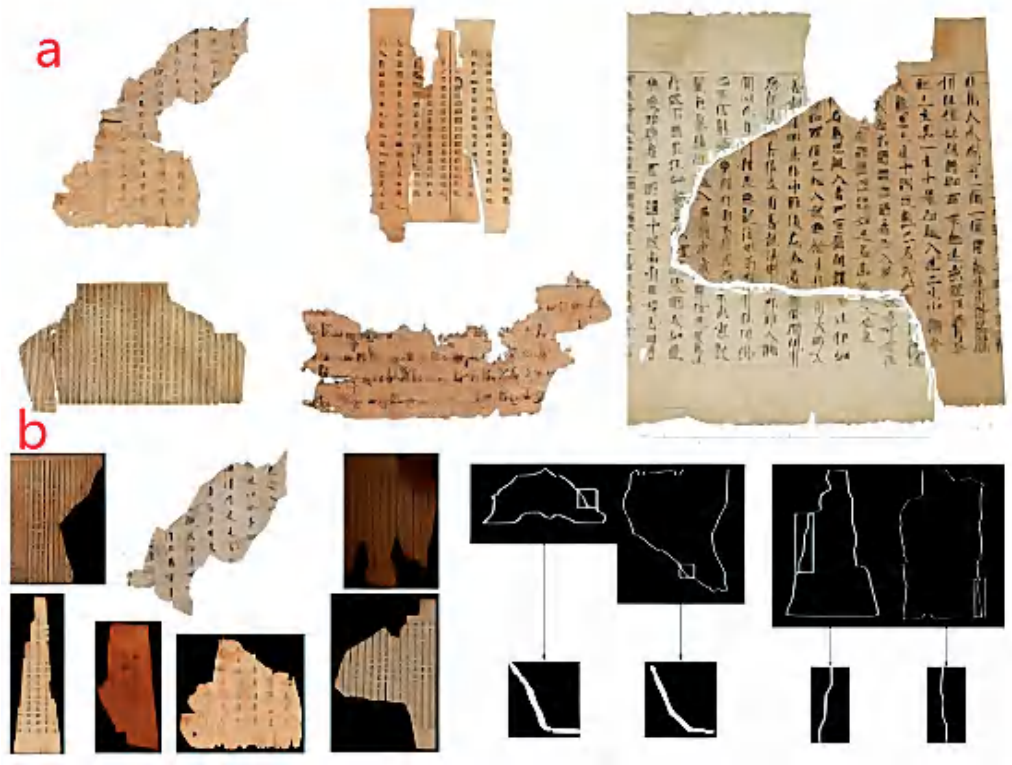
The project builds a full-chain technical architecture encompassing "multi-modal perception — feature fusion — intelligent retrieval — human-machine validation." The perception layer decouples fragment information into four complementary dimensions: the edge geometry dimension introduces dynamic point cloud networks to extract rotation-invariant and noise-resistant pure geometric topological features along fragment contours; the calligraphic style dimension leverages a fine-tuned penmanship model to precisely capture the brushstroke dynamics and structural characteristics of ancient scripts; the visual foundation dimension extracts microscopic physical features including paper texture, mold spots, and ink diffusion patterns; and the contextual semantics dimension incorporates an ancient Chinese semantic model optimized for traditional character texts, achieving robust cross-fragment semantic stitching even in heavily damaged scenarios.



Architecture of Duelgraphnet

The project follows a three-phase progressive implementation pathway. In the first phase, it independently develops an area-driven iterative fracture simulation algorithm, generating tens of thousands of highly realistic training samples at low cost by simulating the actual tearing trajectories of paper fibers and high-frequency degradation noise. In the second phase, it aligns multi-source heterogeneous features — including calligraphic style, visual characteristics, and semantics — into a unified data manifold within a high-dimensional latent space, constructing a "form-meaning integrated" feature foundation. In the third phase, it conducts zero-shot testing on real-world fragments, generating front-end matching hypotheses through the model's high-recall retrieval capability, followed by post-processing validation through deterministic physical rule engines, ultimately forming the human-machine collaborative workflow of "machine-driven preliminary screening within seconds — expert one-click validation."

The project's core innovations are embodied in two dimensions: first, the multi-modal dynamic interaction mechanism, which creates an interactive graph mechanism simulating the higher-order cognitive pathway by which human experts synthesize fragmented details into a holistic impression, and introduces an extreme negative bias dynamic gated anti-noise mechanism to significantly reduce false matching rates in complex degradation scenarios; and second, precision dimensionality reduction retrieval capability, achieving high recall and comprehensive accuracy through multi-modal exclusionary constraints, transforming manual reconstruction into a second-level, highly reliable machine-recommended system.



Text Joining Effect Demonstration

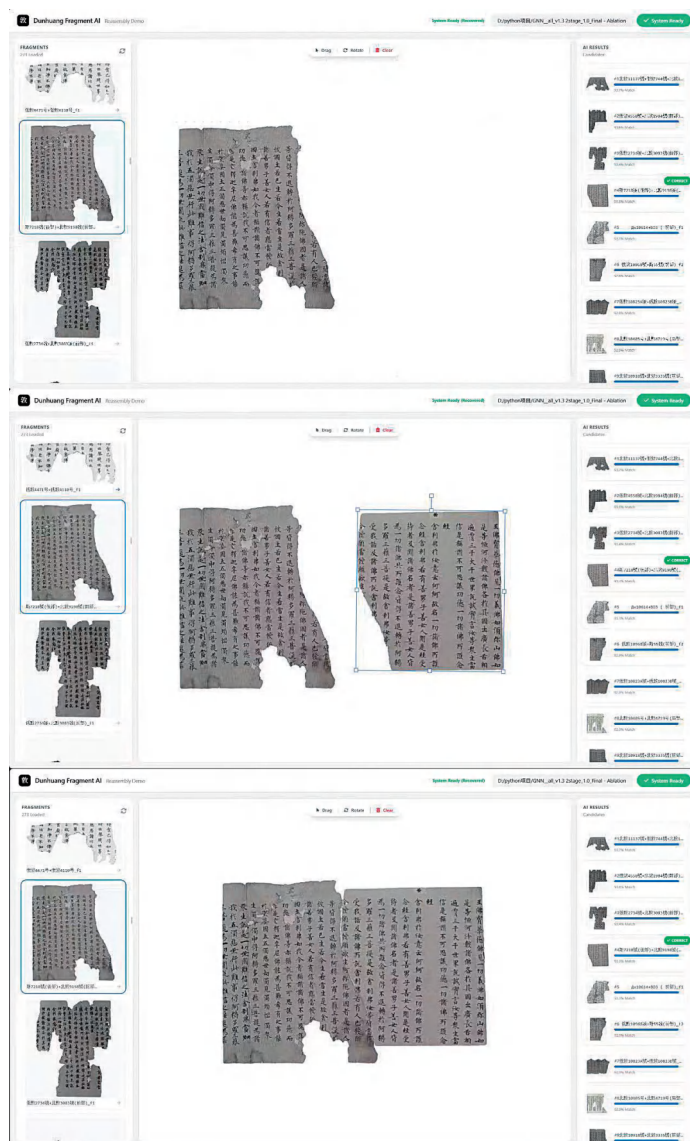
From Laboratory to Real-World Scenario Validation

In cross-domain testing on real-world, complex-degraded ancient manuscript fragments, the system achieved over 90% retrieval recall and comprehensive matching accuracy with zero human intervention. Single cross-feature retrieval is completed in seconds. In large-scale applications, it is projected to save cultural heritage institutions over 80% of the time currently spent on manual verification and comparison, significantly accelerating the rescue preservation of massive fragmented documents. Through cloud-based interactive feature alignment, the project enables cross-institutional "digital reunification" of Silk Road cultural relics scattered overseas with fragments held in domestic collections, removing physical barriers



Application Scenario Demonstration of Ancient Books Activation

to global manuscript studies. The thematic exhibitions supported by the project's outcomes have been featured on China Central Television's Xinwen Lianbo and received in-depth special coverage from mainstream media including People's Daily and Guangming Daily, generating significant social impact. The structured digital assets produced by the system have served over 30 million cumulative users, with deep outcome translation achieved through standardized SaaS interfaces and integrated software-hardware solutions. The project has led the development of 13 industry and enterprise standards, received a total of 32 major national and provincial-level awards, and holds 95 national invention patents and over 100 software copyrights. The team has published over 500 high-level academic papers and 13 academic monographs and core textbooks, contributing significantly to the flourishing development of the interdisciplinary field of "AI + Dunhuang Studies."



Dunhuang Fragment AI

A Transferable Technical Foundation and Cross-Domain Paradigm

The interactive multi-modal reasoning paradigm developed through this project serves as a general-purpose computational foundation for capturing deep isomorphic relationships among unstructured entities. It can be horizontally transferred to various digital humanities restoration tasks, including fragmented ceramic reassembly, mural topological reconstruction, and oracle bone script automatic matching, and vertically generalized to fundamental scientific fields such as drug-target binding prediction. The standardized multi-modal graph-matching SaaS interface and integrated software-hardware solution can be rapidly adapted to the needs of various cultural heritage institutions, significantly lowering the barrier to technology adoption. The human-machine collaborative reassembly paradigm established by the project provides a benchmark reference for intelligent restoration of similar cultural artifacts, breaking through the standardization bottlenecks of traditional digital humanities research.

From Silk Road Fragments to Global Digital Reunification

The project has laid out a three-stage development roadmap. The first stage focuses on computational power and efficiency upgrades, constructing an asymmetric two-stage lightweight retrieval pipeline to break through the computational bottlenecks of massive database retrieval, with pilot applications at two to three core partner museums. The second stage expands application boundaries, enlarging the real-world difficult-sample database, horizontally extending application scenarios from paper manuscripts to murals, oracle bones, and other domains, and introducing large language models for macro-historical context inference and generative visual topological completion capabilities. The third stage advances internationalization, launching a multi-lingual international platform, promoting interconnectivity of the global Silk Road fragment feature database, and organizing a large-scale "Global Digital Reunification" interactive online exhibition.

At the technological level, continuous upgrades are directed toward a general-purpose entity complementary reasoning foundation. The resource security system adopts a cross-disciplinary team configuration of "AI scientists + ancient manuscript scholars + cryptography experts." Funding relies on a three-pronged model of national research grants, institutional procurement by cultural heritage institutions, and commercial cultural and creative licensing. The technology employs a domestically developed, fully autonomous independent and controllable underlying AI framework. To address the risk of AI hallucination-induced stitching errors, a neural-symbolic hybrid system is fully deployed, with all matching results mandatorily filtered through physical rule engines and validated by experts. For cross-border data privacy concerns, federated learning and privacy-preserving computation are introduced to achieve "data usability without visibility," with blockchain-based distributed timestamps and multi-party validation digital credentials ensuring the academic rigor and regulatory compliance of technological applications.



Amul Heritage Digital Initiative



East China University of science and technology

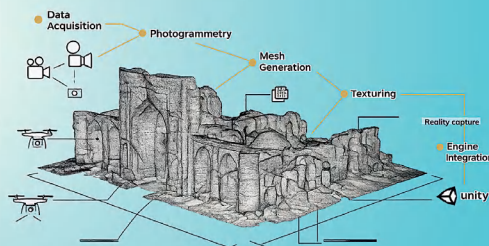


Seyitnazar Seydi Turkmen State Pedagogical Institute



Photogrammetry and AI Preservation of Endangered Silk Road Heritage in Turkmenistan

土库曼斯坦濒危丝绸之路遗产的摄影测量与人工智能保护



Explore our projects



3 HERITAGE SITES Beykhan Sakirli Mashhad	200 FACULTY TRAINED 4000 students 10000+ students	6 PLATFORMS Beykhan Sakirli Mashhad Sakirli Mashhad Sakirli Mashhad
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Photogrammetry and AI Protection of Endangered Silk Road Heritage in Turkmenistan

Applicant Institution

Amul Digital Heritage Initiative

Participating Institution

East China University of Science and Technology; Seyitnazar Seydi Turkmen State Pedagogical Institute

Leveraging the trinity of the Zarafshan-Karakum Corridor in Turkmenistan as a "World Heritage Corridor - Endangered Architectural Complexes - Cultural Carrier of the Silk Road," this project has developed an innovative model for the digital preservation of cultural heritage and public services in resource-constrained regions, centered on low-cost photogrammetry, AI-driven reconstruction, and archive anchoring technologies.

Moving away from conventional, high-cost, equipment-dependent approaches, the project directly addresses four critical challenges: preventive documentation, restoration of historical information, cost control of equipment, and local capacity building. It has completed a full-chain innovation cycle encompassing field data collection, technological integration, platform development, and talent cultivation, culminating in a replicable, scalable, low-cost, and high-precision digital solution for Silk Road cultural heritage. This model offers a significant demonstration for the intelligent preservation of cultural heritage in Central Asia and other resource-constrained regions worldwide.

Heritage at Risk in an Earthquake-Prone Zone and a Strategic Response

The project tackles four major pain points in cultural heritage digitization. First, the lack of preventive conservation measures: in earthquake-prone areas, the absence of efficient documentation methods means that precious heritage may be permanently lost in the event of natural disasters. Second, fragmented historical data: Soviet-era archival records are insufficient for accurate reconstruction, with a vast amount of historical information scattered across disparate sources. Third, prohibitively high equipment costs: import restrictions impede accessibility, leaving grassroots heritage institutions unable to afford professional-grade tools. Fourth, weak local capacity: the lack of a sustainable talent development system means that local teams are often unable to operate independently after technical assistance concludes.

In response, the project has implemented targeted and systematic innovations: exploring low-cost acquisition technologies to overcome equipment constraints, developing archive-integrated reconstruction methods to synthesize fragmented information, introducing AI-powered intelligent modeling to enhance restoration efficiency, and prioritizing local capacity building to establish long-term autonomous monitoring and research systems.



Nisa 3D VR

How Consumer-Grade Equipment Achieves Heritage-Grade Precision

The project has established a lightweight technical framework characterized by "consumer-grade equipment, multi-platform collaboration, and AI enhancement," enabling comprehensive data

acquisition across diverse scenarios including open-air sites, confined spaces, damaged structures, and museum collections. Employing technologies such as photogrammetry, LiDAR, neural rendering, and archival rectification, it achieves high-precision, high-efficiency, and low-cost digital reconstruction, attaining heritage-grade measurement accuracy without the use of professional laser scanning equipment. Following a progressive implementation roadmap—from indoor testing, to site validation, to ruin reconstruction, to platform construction, and finally to nationwide promotion—the project



Seyitjemaletdin mosque nowadays (by photogrammetry)



Seyitjemaletdin mosque restoration

digitized museum collections in 2020, completed full-site digitalization of the ancient fortress of Nisa in 2021, and achieved high-precision digital restoration of an earthquake-damaged mosque in 2024. Concurrently, an online platform was launched and nationwide talent training initiatives were carried out, forming a complete and scalable implementation paradigm.

The project has delivered innovations across five dimensions: establishing a control-point-free metric reconstruction method anchored by historical archives; developing a confidence-based transparent virtual presentation system to prevent historical misinterpretation; creating parametric modeling tools for Timurid architectural vaults to significantly improve reconstruction efficiency; establishing application benchmarks for smartphone-based LiDAR in earthen architecture; and building a nationwide distributed talent network for heritage digitization to ensure sustainable localization of technology.

US\$3,500 in Equipment Leveraging International Standards

The project has completed high-precision digital archiving of multiple world-class heritage sites, including the ancient fortress of Nisa and the Seyit Jamal ad-Din Mosque, achieving geometric accuracy that meets international heritage standards. With equipment investment of less than US\$3,500, the project has delivered results comparable to those conventionally attained through hundreds of thousands of dollars in funding, while AI-driven modeling and parametric design have



XV century pottery

significantly shortened reconstruction cycles. Through a nationwide university training program covering 19 higher education institutions and over 200 faculty members, the project is continuously cultivating a new generation of heritage digitization professionals, thereby building local independent conservation capacity. Additionally, 3D-printed tactile models have been produced to promote accessible cultural experiences and public education.

The project embodies a mutually beneficial and equitable model of China-Turkmenistan cooperation, with China contributing AI and digital technologies and Turkmenistan providing local research, archival resources, and field expertise. The outcomes align with UNESCO's strategic directions for Silk Road cultural heritage preservation and offer an important demonstration for cultural heritage digitization in developing countries.

A Replicable Model of "Four Pillars"

The case has developed a model centered on "low-cost equipment, modular workflows, localized implementation, and open platforms," providing a universally applicable pathway for heritage conservation in earthquake-prone regions, resource-limited countries, and areas along the Silk Road. The standardized toolkit generated by this project can be rapidly adapted to different site typologies, and the technical methodology can be transferred and applied without the need to build from scratch. These four dimensions are mutually reinforcing, forming a closed-loop system for comprehensive heritage digital preservation.

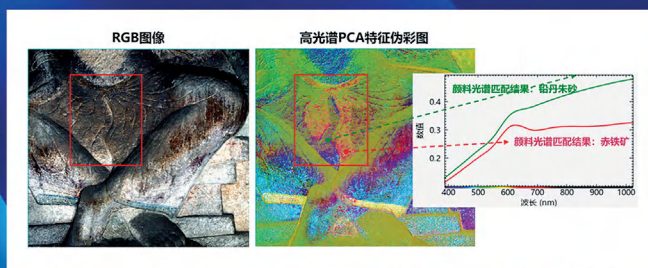
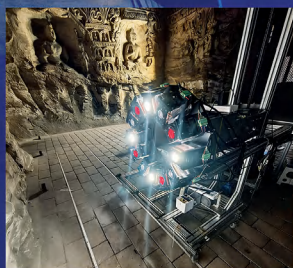
A Three-Phase Roadmap: Building a Digital Heritage Hub for the Silk Road in Central Asia

The project is advancing through three phases: "validation and maturation - corridor-wide coverage - establishment of a national platform." From 2025 to 2026, the focus will be on digitizing mausoleums, caravanserais, and other site types, with the launch of a full-featured multilingual online heritage platform. From 2026 to 2027, the project will expand to additional ancient cities and sites, introducing an AI-powered crowdsourced collection system to broaden recording coverage. From 2027 to 2030, the goal is to complete full digital archiving of the Amul-Merv Corridor, establish Central Asia's first national-level digital heritage platform for the Silk Road, and build a sustainable, scalable, and shareable digital twin system. Upon completion, the platform will be open to researchers and the public worldwide, serving as a core digital resource repository for Silk Road cultural heritage.

Looking ahead, the project will continue to deepen technological innovations in intelligent reconstruction, data fusion, and lightweight presentation, while strengthening data security and copyright management. It aims to propel heritage digital preservation from static documentation toward dynamic monitoring and smart management, sustaining the high-quality digital transformation of Silk Road cultural heritage.

Deciphering the "Fingerprints" of Millennia-Old Grottoes

3D Hyperspectral Data Acquisition of Caves 7 and 8 at the Yungang Grottoes



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Deciphering the "Fingerprints" of Millennia-Old Grottoes: 3D Hyperspectral Data Acquisition of Caves 7 and 8 at the Yungang Grottoes

Applicant Institution

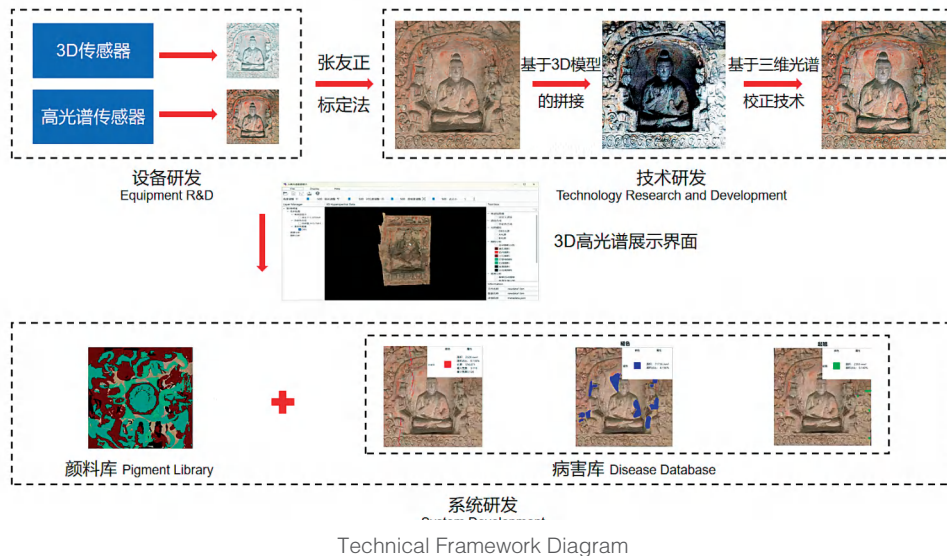
Yungang Academy

Participating Institution

Sun Yat-sen University; Guangzhou Guangxin Technology Co., Ltd; Datong Yungang Digital Technology Co., Ltd.

The Yungang Grottoes stand at the confluence of three defining roles: a UNESCO World Cultural Heritage site, a large-scale grotto architectural complex, and a carrier of Silk Road art from the Northern Wei Dynasty. Grounded in this trinity, the project has developed an innovative model for comprehensive holographic digital preservation of large three-dimensional grottoes, centered on self-developed 3D hyperspectral equipment, multi-modal data fusion, and intelligent spectral analysis.

The project departs from conventional geometry-based digitization approaches and directly tackles three critical challenges: holographic documentation of grottoes, spectral acquisition of large three-dimensional cultural objects, and cross-category data interoperability. It has completed a full-chain effort encompassing equipment development, algorithmic iteration, platform construction, and practical deployment, resulting in a 3D hyperspectral digital preservation solution that is tailored for stone cultural objects and replicable across industry applications. This offers a benchmark paradigm for the intelligent preservation of grotto temples and large immovable three-dimensional cultural heritage sites nationwide.



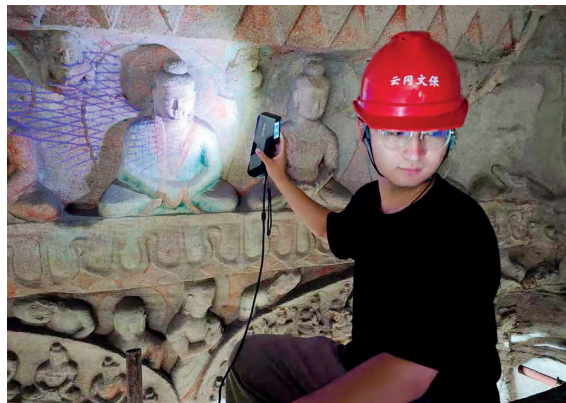
Technical Framework Diagram

The Challenge of Missing Holographic Archives and Spectral Acquisition

The Yungang Grottoes have been digitally documented using 3D laser scanning and close-range photogrammetry, yet three major deficiencies persist in industry-wide digital conservation. First, the absence of holographic documentation: current records contain only geometry and texture information, lacking data on pigment composition, physiochemical deterioration characteristics, and subsurface material properties, which are essential for origin tracing, polychrome restoration, and precision conservation. Second, technical bottlenecks in spectral acquisition for large three-dimensional cultural objects: off-the-shelf hyperspectral equipment is only suitable for planar objects such as paintings and murals. Due to limitations in imaging principles and correction algorithms, these systems cannot achieve full-area spectral acquisition of large curved immovable objects like grottoes and ancient architecture—a globally recognized technical challenge in heritage conservation. Third, the severe fragmentation of multi-modal data: 3D point clouds, imagery, and spectral data are stored independently, lacking registration and interoperability, which hinders the implementation of preventive conservation. This project focuses its technical research on three major directions: spectral acquisition for large three-dimensional cultural objects, 3D spectral correction, and multi-modal data fusion.

Building from Scratch: Self-Developed Equipment Breaking Through a Global Technical Barrier

The project has established an integrated 3D hyperspectral technical system encompassing "hardware acquisition - algorithmic processing - platform analysis." A self-developed temperature-controlled wide-spectrum LED cold-light source 3D hyperspectral acquisition device was created, integrating three core modules: a high-resolution hyperspectral camera, an iToF 3D depth sensor, and a multi-angle adjustable bracket. The light source covers a wavelength range of 400 - 1000 nm with a spectral resolution better than 2.8 nm and point acquisition accuracy reaching 0.6 mm, while operating under low-light, low-heat conditions that are fully compliant with grotto conservation protocols. On the algorithmic front, two core innovations were developed: a 3D point cloud template-based spectral stitching algorithm that eliminates frame parallax misalignment and error accumulation; and a 3D irradiance reflectance correction model adapted to the curved surfaces of



3D laser scanning work



Hyperspectral work

grottoes, correcting spectral distortions caused by illumination and viewing angles. A companion 3D hyperspectral analysis platform was also developed, integrating model fusion, pigment identification, deterioration annotation, and virtual restoration into a unified workflow.

Following a closed-loop roadmap of "equipment development – pilot cave trial – full-site implementation – review and optimization," the project completed equipment development and calibration in Cave 10 from February 2024 to February 2025. From May to October 2025, full-site 3D hyperspectral acquisition and multi-modal data integration were carried out in Caves 7 and 8, completing end-to-end validation.

The project has achieved five major innovations: self-developed cold-light source acquisition equipment dedicated to cultural objects, enabling full-area lossless spectral acquisition of large immovable grottoes; pioneering simultaneous 3D and hyperspectral dual-sensor registration technology, achieving cross-modal high-precision fusion of geometry, spectral, and texture data; implementing 3D spectral correction technology for curved cultural objects, overcoming the challenge of spectral distortion on three-dimensional artifacts; achieving spectral complementation for occluded and multi-angle areas, completing full-site grotto spectral data coverage; and building a dedicated integrated analysis platform, establishing a complete technical chain from acquisition to conservation application.

From Monochrome Geometry to Holographic Archives: How Material Documentation Reshapes Conservation Logic

The project represents an upgrade of Yungang Grottoes digitization from geometric recording to material archival. A spectral database of pigments and deterioration features has been established, enabling accurate identification of historical pigment residues and restoration traces, as well as analysis of the causes of weathering and efflorescence. This shifts conservation from reactive emergency response to predictive, minimally invasive precision restoration. Spectral data have enabled the reconstruction of the original polychrome appearance of the grottoes, transcending the limitations of monochrome geometric models. By breaking through the spectral acquisition bottleneck for large

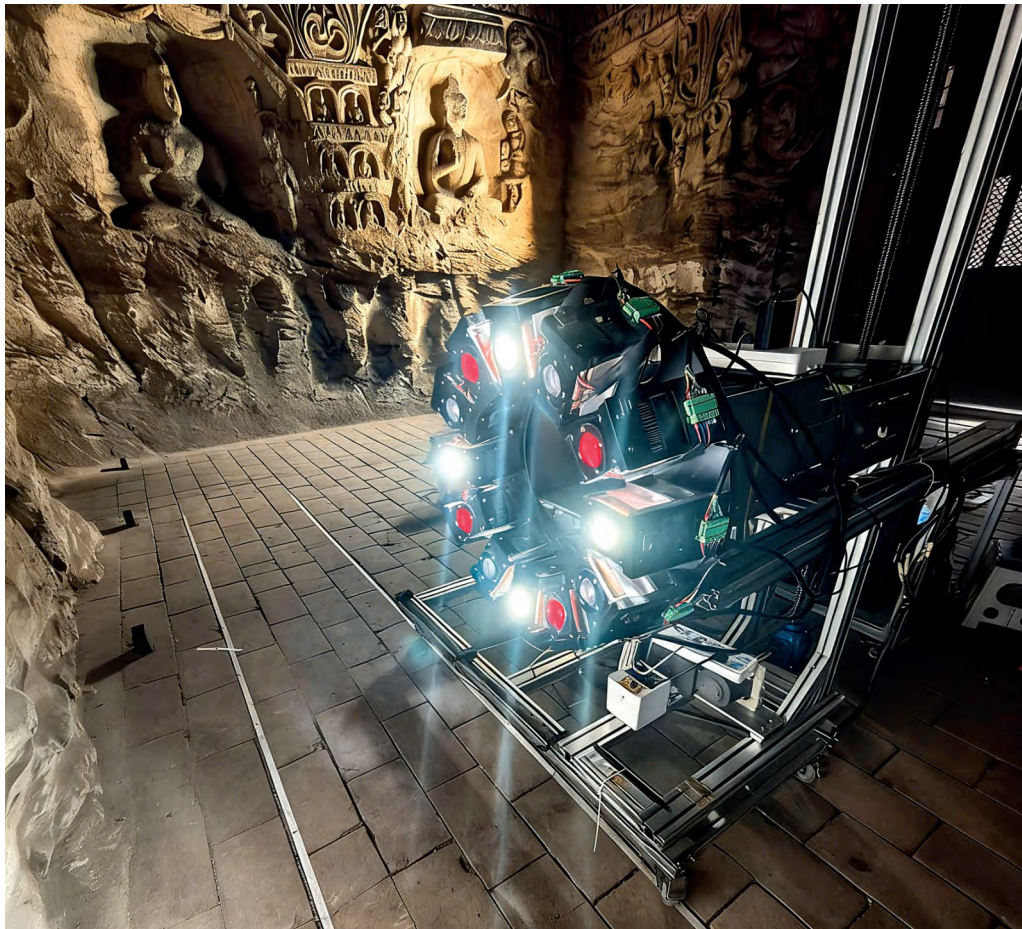


Illustration of the effect of three-dimensional hyperspectral reflectance correction

three-dimensional cultural objects, the project has created a localized, self-developed equipment paradigm, with acquisition precision improved by orders of magnitude compared to traditional methods, capable of monitoring micro-scale fissure changes.

Standardized Operational Protocols and Cross-Scenario Adaptability

The project has developed standardized protocols for acquisition, correction, fusion, and archiving across the entire workflow. The comprehensive technical system is adaptable to a wide range of three-dimensional cultural objects, including grotto temples, ancient architecture, and large polychrome sculptures, as well as diverse scenarios such as open-air sites and enclosed cave spaces, enabling rapid replication and scaling across cultural heritage institutions nationwide. The technical solution does not rely on imported equipment, with the entire chain being independently developed and controlled, offering a directly adoptable localized equipment pathway for peer conservation institutions.



Equipment (front)

Equipment Iteration and Industry Standard Development

Looking forward, the project will focus on three major directions: equipment iteration, technical breakthroughs, and outcome translation. Plans include developing lightweight and lift-enabled versions of the equipment and advancing production scaling to lower deployment barriers; tackling large-volume multi-modal fusion and spectral lightweighting technologies to improve data processing efficiency; publishing five high-level research papers and formulating industry standards. Concurrently, the project will pursue multi-scenario equipment adaptation, AI-driven intelligent monitoring, patent applications, and international and national standard development, promoting the application of 3D hyperspectral technology from Yungang to the front lines of grotto temple conservation across China.

From the National Catalogue to the Knowledge Graph: ICCD's Public Catalogue, ArCo, Cat-IA and the Transition to CLIO

Transforming Italy's national cultural heritage catalogue from record-based documentation into a semantic, public, interoperable knowledge infrastructure

Carlo Birrozzi, Fabrizio Magnani, Elena Musumeci
ICCD - Istituto centrale per il catalogo e la documentazione



The Italian Ministry of Culture and ICCD protect cultural heritage by producing authoritative knowledge on tangible and intangible cultural assets. Cataloguing is therefore not only a descriptive activity: it is a strategic tool for identification, safeguarding, conservation planning, public access, and long-term cultural responsibility. Through CLIO, ICCD is transforming cataloguing into a semantic, geospatial, and interoperable national knowledge infrastructure.

Case Background

A national infrastructure for cultural heritage protection
ICCD manages the General Catalogue of Cultural Heritage as a national knowledge base supporting the documentation, protection, and public understanding of Italy's cultural heritage. The cataloguing system is therefore central to the Ministry's institutional mission of safeguarding cultural assets.

From isolated records to contextual knowledge
Traditional cataloguing systems have often represented cultural assets as individual records. CLIO responds to the need to reconnect assets with their historical, territorial, documentary, social, and institutional contexts.

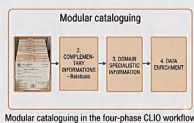
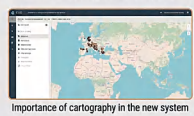
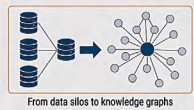
The challenge of fragmented data
Cultural heritage information is distributed across records, archives, photographs, multimedia resources, authority files, regional systems, and external datasets. The case addresses the need to overcome silos and enable coherent data circulation.

The importance of semantic interoperability
ICCD's transition toward Linked Open Data and ArCo has made it possible to represent cultural heritage as a knowledge graph, where objects, places, agents, events, collections, and contexts become interconnected entities.

Cartography as a knowledge and protection layer
The geographical dimension is essential for understanding cultural heritage: location, provenance, discovery place, current conservation place, and territorial context are key elements for protection, planning, emergency management, and interpretation.

Toward international and multilingual cooperation
The case also responds to the need for multilingual vocabularies, shared semantic models, and comparative cataloguing practices, especially in relation to extra-European collections preserved in Italian museums and to international cooperation projects.

Case Innovation & Practice



Modular cataloguing in the four-phase CLIO workflow

Semantic-Native Knowledge Infrastructure
CLIO transforms cataloguing from downstream Linked Open Data publication into native semantic data production. Cataloguing data are generated from the outset as interoperable, graph-ready knowledge connected to the ArCo ontology network. The knowledge graph becomes an operational layer of the system, linking cultural assets, context entities, multimedia resources, vocabularies, and geodata.

Modular, Geospatial and Contextual Cataloguing
CLIO replaces rigid record templates with a modular and incremental model: a minimum identification core can be enriched through general and specialist modules. Advanced GIS tools, interactive maps, geocoding, spatial search, historical cartography, and interoperable geoservices allow cultural heritage to be understood as a territorial system of relations.

Semantic Terminology and AI-Assisted Access
Controlled vocabularies, thesauri, ontologies, and descriptive models become active instruments for knowledge organization. SKOS-based vocabulary management supports hierarchy, equivalence, reuse, versioning, and future multilingual development. Cat-IA and future AI services assist discovery, data cleaning, transcription, image analysis, and natural-language access while preserving expert validation and institutional reliability.

Future Perspectives and Work Plan

Core Phase and Strategic Continuity
The core phase of CLIO will be completed in July 2026. Further developments will immediately follow, consolidating CLIO as a strategic national infrastructure for cultural heritage protection, semantic interoperability, geospatial knowledge, and international cooperation.

Multilingual Semantic Resources
Future work will focus on multilingual thesauri and lexical resources developed with international partners. These tools will support semantic mediation, conceptual alignment, and more responsible documentation of culturally diverse and extra-European collections.

Cartography, Provenance and Heritage Relations
CLIO will strengthen geospatial layers to document provenance, object trajectories, historical circulation, and territorial contexts. Historical cartography will support diachronic interpretation, while semantic modelling will connect tangible heritage with practices, techniques, oral traditions, and communities of transmission.

International Cooperation, Benefits and Risk Governance
International cooperation will support comparative cataloguing on shared themes such as rural architecture, vernacular heritage, traditional techniques, and intangible heritage. Expected benefits include stronger protection, data reuse, public access, interoperability, and intercultural dialogue, with risks mitigated through expert validation, phased pilots, shared standards, and vocabulary governance.

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From the National Catalogue to the Knowledge Graph: ICCD's Cultural Heritage Catalogue, ArCo, Cat-IA and the Transition to CLIO

Applicant Institution

Central Institute for Catalogue and Documentation (ICCD), Italy's Ministry of Culture

Six Critical Gaps in Cultural Heritage Cataloguing

There is a clear consensus across Italy's cultural heritage sector: cataloguing constitutes the core foundation of heritage conservation, fulfilling the full spectrum of functions including artifact authentication, location-based archiving, condition monitoring, legal registration, and contextual interpretation. However, the current cataloguing system in Italy faces six critical gaps that hinder its effectiveness: severe fragmentation of heritage archives across institutions; weak interoperability of cross-platform data; inability to digitally express the humanistic context of heritage; marginalization of geospatial information management; static and non-interoperable specialized vocabularies; and low public accessibility due to high barriers to professional data entry. Meanwhile, the growing volume of cross-border collections necessitates a multilingual, cross-cultural international cooperative cataloguing framework.



intangible interdisciplinary archiving needs. The fifth is comprehensive structured geographic archiving, integrating spatiotemporal data and historical-locational mapping to enable heritage provenance research, territorial planning, and emergency management. The sixth is ontology-constrained intelligent services, leveraging Graph RAG technology to build the Cat-IA exclusive AI tool, which anchors output to expert-validated knowledge bases to mitigate the risk of AI-generated semantic distortion.

Following a smooth-transition principle, the project is being implemented in four phases: assessing deficiencies in legacy systems and deconstructing user business requirements; launching linked open data and building a full-domain semantic ecosystem; refining the CLIO native production system to achieve integrated semantic data output; and connecting with national cultural heritage platforms to enable interoperability of multimedia archives and cross-domain knowledge graphs.

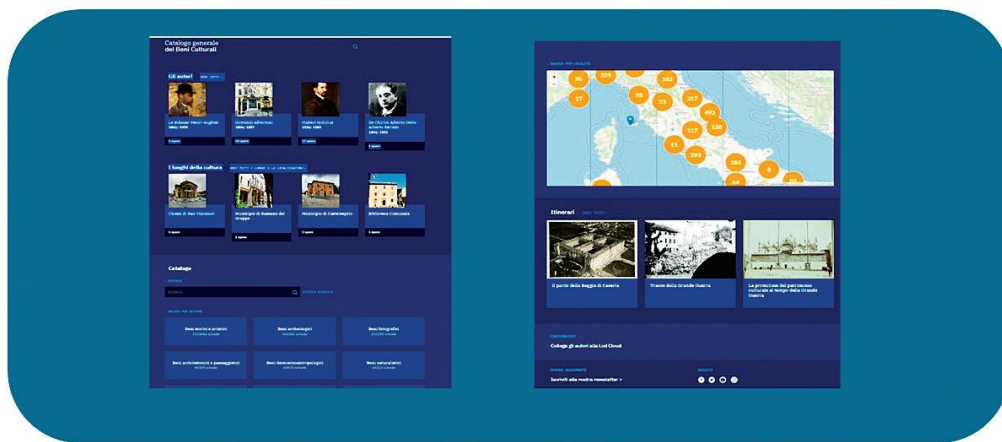
The project has achieved seven core breakthroughs: realizing heritage knowledge graph production; closing the loop between digitization and heritage conservation; implementing native semantic cataloguing; promoting flexible modular archiving; establishing the centrality of geospatial cataloguing; activating SKOS-linked semantic vocabularies; and building a compliant and controllable AI application system for the cultural heritage sector.

Semantic Cataloguing: Transforming Archives from "Cold Records" to "Living Resources"

The platform has seen annual unique visitors surge from 100,000 to 2 million. Semantic cataloguing has dramatically lowered the barrier to professional data, transforming archival records previously



accessible only to specialists into open knowledge resources that can be understood, searched, and reused by the general public. Structured geographic archiving has empowered provenance research, territorial planning, and emergency management, upgrading cataloguing data from static records to dynamic governance tools. The launch of the Cat-IA exclusive AI tool has enabled cataloguing professionals to efficiently perform semantic annotation under the constraints of expert-validated knowledge bases, ensuring both data quality and significant improvements in operational efficiency. The project has distilled six globally transferable lessons: low-risk phased iterative transformation; semantic technology empowering heritage conservation; modular adaptation to diverse heritage typologies; geographic archiving integrated with territorial management; collaborative governance of standardized vocabularies; and cost-controllable AI deployment — all of which are adaptable to national-level heritage system reforms in various countries.



Visualization of Cultural Heritage

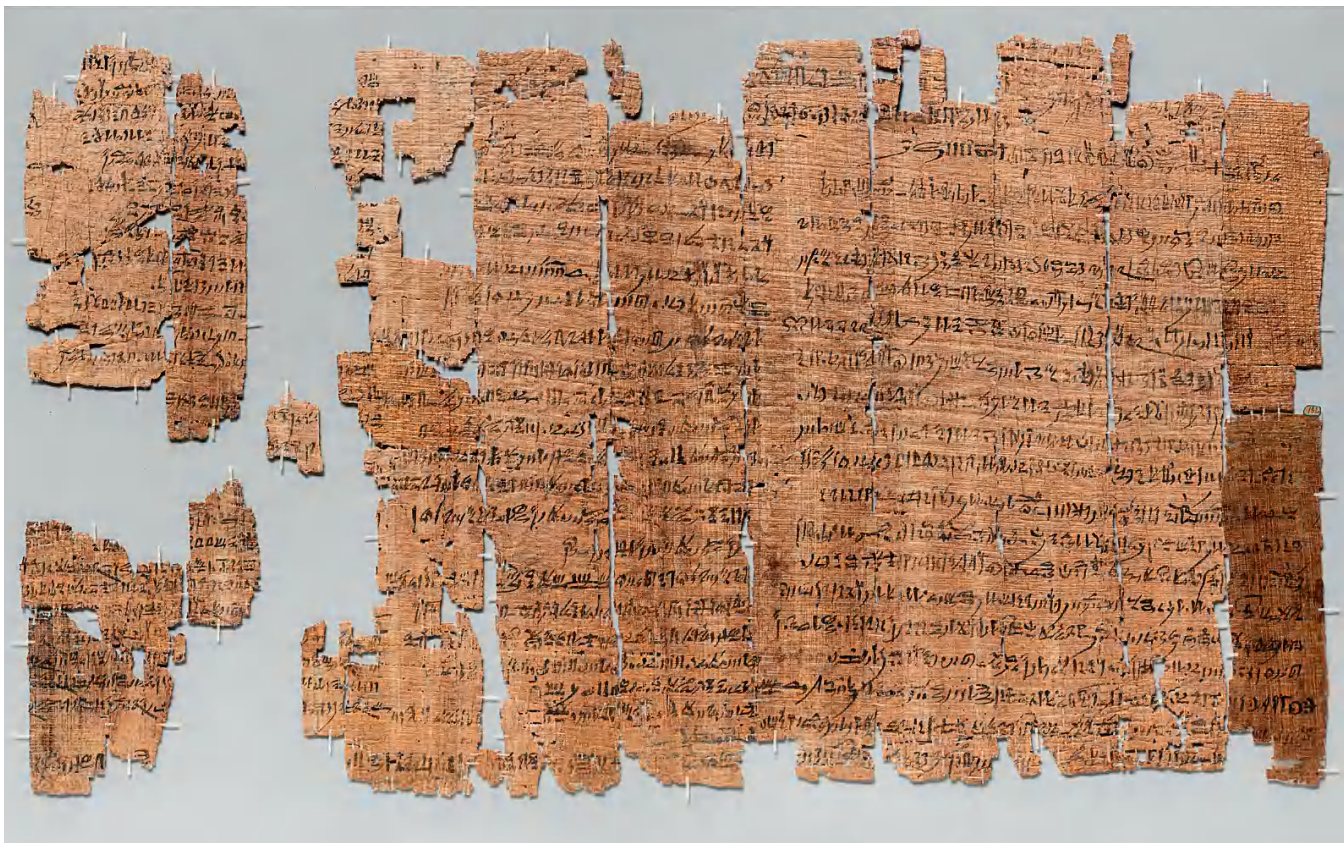
A Future-Oriented National Knowledge Infrastructure

The project has established a four-phase standardized implementation roadmap: by July 2026, the core system architecture will be completed; from July 2026 to June 2027, multilingual vocabularies and intangible heritage association models will be developed, and cross-border partner institutions will be confirmed; from July 2027 to December 2028, pilot cataloguing projects will be implemented for cross-border collections, vernacular heritage, and intangible cultural heritage; and from 2029 to 2030, standardized methodologies will be disseminated nationwide, and the CLIO cataloguing transformation model will be promoted.

On the technical front, the project focuses on four major directions: co-developing cross-border multilingual SKOS thesauri; deepening geospatial modeling of heritage spatiotemporal circulation; refining relational modeling between tangible and intangible heritage; and iterating expert-finalized AI-assisted cataloguing tools. On the application front, the project targets five implementation scenarios: national-level heritage risk management; provenance research and circulation tracking of museum collections; transnational thematic collaborative cataloguing; equitable cultural dialogue on cross-border collections; and inclusive public cultural heritage education.

Funding is secured through a dual-track model combining dedicated innovation funds and ordinary appropriations from the Italian Ministry of Culture. Interdisciplinary teams comprising cataloguing, GIS, AI, and humanities specialists have been assembled to support operations and maintenance. International cooperation adheres to a principle of methodology sharing rather than technology export, engaging multiple countries in joint development of terminological systems, collaborative collection cataloguing, and refinement of international industry standards.

Furthermore, the project has identified six major risks— terminological misalignment, technological overload, legacy data imperfections, AI misuse, cross-cultural cognitive bias, and funding discontinuity — and has formulated mitigation measures including expert collaborative governance, phased piloting, data validation, human final review, and diversified fundraising, all aimed at building a global benchmark project for semantic heritage cataloguing.



Reconstructing fragmented written heritage through a digital research infrastructure

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Applicant Institution

Museo Egizio (Egyptian Museum of Turin)

This case operates at the intersection of digital cultural heritage, integrating multidisciplinary theories from papyrology, heritage conservation, and digital humanities. Leveraging internet-based digital infrastructure, it has developed the Turin Papyrus Online Platform (TPOP), a collaborative online research platform that enables coordinated data organization, shared standards development, and transnational academic cooperation.



Moving beyond conventional approaches of artifact digitization and offline manual research, the project confronts the inherent attributes of ancient textual remains — fragmentation, dispersion, and interpretive diversity — and restructures the entire workflow for archiving, reconstructing, and interpreting damaged textual artifacts. It has established an open, cross-border collaborative digital ecosystem that accommodates standardized museum collection management, global scholarly research, and public cultural education, offering a replicable digital paradigm for the conservation of dispersed and fragmentary textual heritage worldwide.

The "Three-Millennium Predicament" of Papyrus Heritage

Ancient Egyptian papyrus is an exceptionally fragile textual medium, highly susceptible to weathering and deterioration. Global collections are dispersed across institutions and managed in isolation, and the digital conservation of this heritage faces four critical challenges. First, the tension between conservation and research: the physical fragility of papyrus means that repeated physical retrieval and manual joining accelerate deterioration, while the sheer volume of fragments precludes comprehensive comparative study. Second, fragmented collection data systems: cataloguing standards for papyrus collections vary across museums worldwide, provenance and circulation records are incomplete, and cross-institutional fragment correlation remains unachievable. Third, the limitations of traditional research models: past scholarship relied heavily on individual expertise in comparing handwriting, ink, and fiber patterns — a subjective and inefficient process that leaves no traceable reasoning, produces results that are difficult to verify or share, and cannot scale to the systematic study of over 30,000 fragments. Fourth, the lag in digital development of the discipline: Egyptology lacks an interoperable open research platform; various textual databases remain isolated, unable to interface with global digital heritage resources,



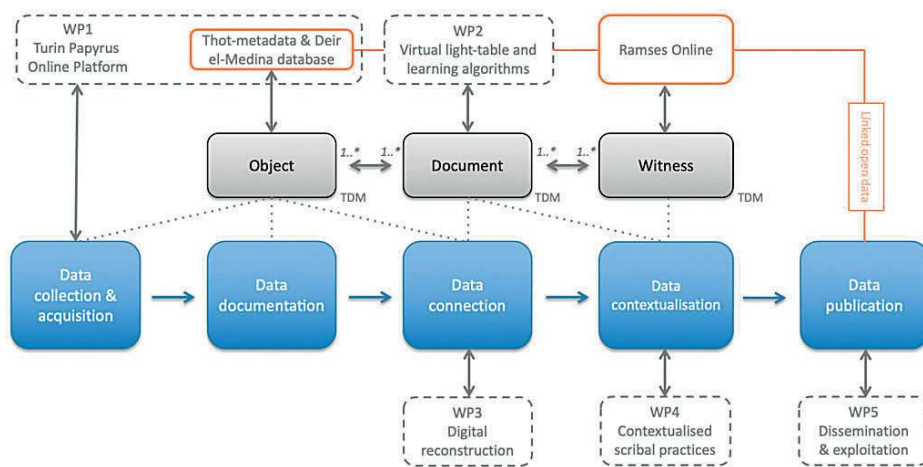
papyrus fragments

impeding transnational comparative research and interdisciplinary exchange.

Museo Egizio (Egyptian Museum of Turin), home to the world's largest collection of ancient Egyptian papyri spanning three millennia and multiple languages, faced a backlog in cataloguing and publication, prompting the launch of the TPOP.

Making Fragments "Speak" in the Cloud

Adhering to the principles of artifact-first, scholarship-driven, iterative implementation, and long-term sustainable operation, the project has established a full-chain workflow encompassing "lossless acquisition - standardized database - online collaboration - human-machine verification."



TPOP workflow and work packages

The implementation follows a progressive path: first, lossless high-resolution digitalized papyrus collection data collection and acquisition, coupled with conservation treatment of fragile fragments, to build a standardized image and physical database that enables remote online access and eliminates frequent physical handling. Second, unified cataloguing rules are applied across the entire collection, with provenance metadata supplemented and linked open data and persistent identifiers aligned with international standards, opening interoperability with global databases. Third, a multi-user collaborative platform is launched, granting permissions for annotation, transcription, and editing, and fostering an international online research community.

The project has achieved five major breakthroughs. First, it reconfigures the logic of scholarly interpretation: treating fragmentation and interpretive divergence as inherent attributes of civilization, it establishes a three-tier independent yet linked architecture—physical fragments, reconstructed manuscripts, and textual transcriptions—allowing multiple interpretations to coexist. Second, it revolutionizes reconstruction practices: replacing highly risky physical assembly with online virtual practice while retaining complete chains of evidence. Third, it establishes a compliant human-machine collaboration mechanism: introducing computer vision and machine learning for character segmentation and pattern classification, while strictly adhering to the human-in-the-loop principle, with all algorithmic results subject to final review by humanities experts. Fourth, it builds a decentralized transnational collaboration system: removing institutional and national barriers to enable joint scholarly



Heterogenous Papyrus light

research across borders. Fifth, it creates a modular and extensible underlying architecture, applicable to a wide range of ancient textual artifacts including ostraca, parchment, and other manuscript traditions.

From "Wear-and-Tear" to "Permanent Access"

On the conservation front, the project has achieved one-time capture and permanent reuse of papyrus fragments, fundamentally reducing physical handling and damage. It has completed standardized digital archiving of over one thousand manuscripts and more than 30,000 fragments from the Turin collection, establishing a long-term protective baseline for endangered textual heritage. On the research front, it has broken down national and institutional data silos, filling a critical gap in the digital infrastructure of Egyptology. The digitization of research workflows has eliminated the drawbacks of purely individual expertise, substantially improving both the efficiency and reliability of fragment reconstruction. On the industry front, it has established standards for trustworthy AI in the humanities, defining a clear human-machine boundary in which algorithms assist and experts finalize,

MUSEO EGIZIO
1824 — 2024

Documents - <https://papyri.museoegizio.it/d/185>

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Translation (Italian)

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Text Direction:

Left to right



Right to left



Text Orientation:

Horizontal

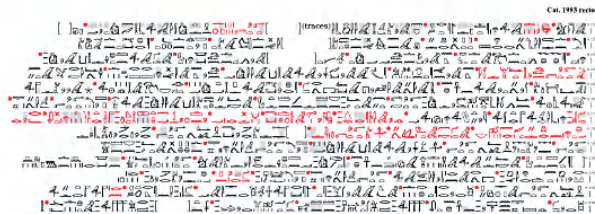


Vertical

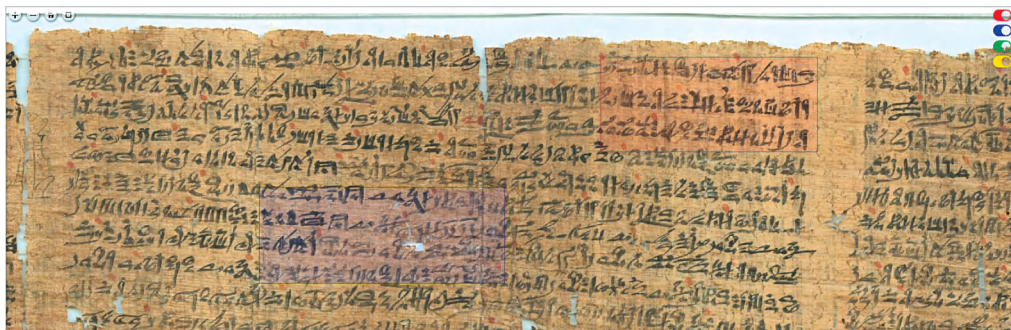


Render

Hieroglyphs



Document 185 - Magical papyrus Isis and Re



NOTES

Comments Text	25/04/2025 10:39	style1	TEST 2	
Comments Materiality	25/04/2025 10:38	style1	TEST 1	

TPOP

providing a model for the compliant and intelligent development of digital humanities. On the social front, the platform opens academic resources to the public, enabling global educational access and promoting broader understanding of ancient Egyptian civilization, while continuously enhancing its international impact.

From Turin to the World: A Replicable Paradigm for Textual Heritage Conservation

The project is advancing through three iterative phases. Phase I focuses on improving AI training datasets, optimizing online collaborative annotation tools, and launching pilot transnational collection data sharing initiatives. Phase II expands the platform's adaptability to additional artifact types, integrating multispectral and 3D visualization technologies to cover a broader range of ancient textual materials. Phase III aims to establish a self-sustaining operational framework independent of project-based funding, while leading the development of international standards for the digitization of damaged textual heritage.

Looking ahead, the project will continue to prioritize scholarly needs over technological drivers, aligning with international digital heritage standards. Its modular architecture and open-access licensing framework balance institutional data sovereignty with global collaboration, enabling low-cost deployment across museums and research institutions of varying scales, and providing a fully replicable digital paradigm for the global promotion of transnational collaborative textual heritage conservation.

申报单位：中国国家博物馆、
天津恒达文博科技股份有限公司

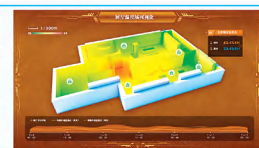
基于多维环境感知与数理 模型预测的博物馆 藏品预防性保护系统

藏品预防性保护是一项融合多学科知识与跨专业技能的综合业务领域。本团队以文物保护的基础研究成果为依托，结合建筑技术学理论，通过构建数学模型实现预测性分析，从而推动博物馆从经验主导的传统模式向数据驱动的智能保护方向转型。旨在有效解决实际工作中存在的数据利用不足、系统功能智能化水平较低等问题，并探索从理论研究到技术研发，再到工程实践的数智化发展路径。

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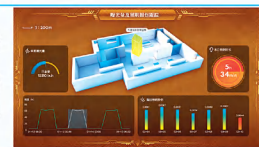
环境场可视化

- 基于有限且离散的监测点上传的数据，通过数据同化与插值算法预测空间场内其他点位的数据
- 借助数字孪生技术实现环境场分布的连续化、可视化与动态化呈现
- 直观掌握展览空间环境的整体分布特征及其变化规律，为局部环境调控和空间布局优化提供依据



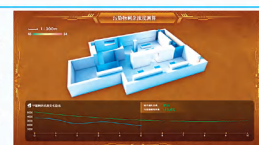
照明损伤测算

- 基于照明损伤数学模型，对不同材质文物与照射强度、照射时长及照明损伤之间的耦合关系进行量化分析
- 在展陈策划阶段，依据设计条件制定照明方案，并预测可能产生的光损伤结果
- 通过跟踪文物展品的年度曝光量及其已累积的光损伤情况，动态调整展陈计划与光源参数



污染物浓度预测

- 基于扩散模型，通过输入材料参数、温湿度数据、换气间隔及对流系数等因子，预测展陈在开放一定时间后的污染物浓度
- 协助博物馆量化文物暴露风险、验证通风策略，并构建突发污染事件的演变模型
- 通过对真实监测数据与预测数据的对比分析，持续优化迭代相应的数学模型。



藏品风险管理

- 基于环境监测与预警结果，对藏品所处环境的风险进行识别与评估
- 针对展览、保管等不同场景中的藏品风险开展评价，为预防性保护策略的实施提供科学依据
- 通过风险分级管理，实现藏品保护资源的优化配置



Preventive Conservation System for Museum Collections based on Multi-Dimensional Environmental Sensing and Predictive Modeling

011

Applicant Institution

National Museum of China

Participating Institution

Tianjin Hengda Cultural Relics and Museums Technology Co., Ltd.; Harbin Institute of Technology; Tsinghua University; Tianjin University

This case focuses on the field of intelligent environmental monitoring and risk early warning for museum collections preservation. Integrating multidisciplinary theories from the Internet of Things, big data, 3D visualization, and building physics, it has constructed a five-tier collaborative technical architecture encompassing "perception - networking - data - algorithms - applications," establishing a preventive smart preservation platform for museum exhibition spaces.

Addressing common industry challenges such as single-dimensional environmental monitoring, lack of predictive capabilities, and insufficient intelligent integration, the project identifies environmental field reconstruction, quantitative damage assessment, and proactive early warning and regulation as its core breakthroughs. It has developed a replicable and scalable digital preservation paradigm, offering a practical model for the cultural heritage sector's transition from "passive remediation" to "active prevention."

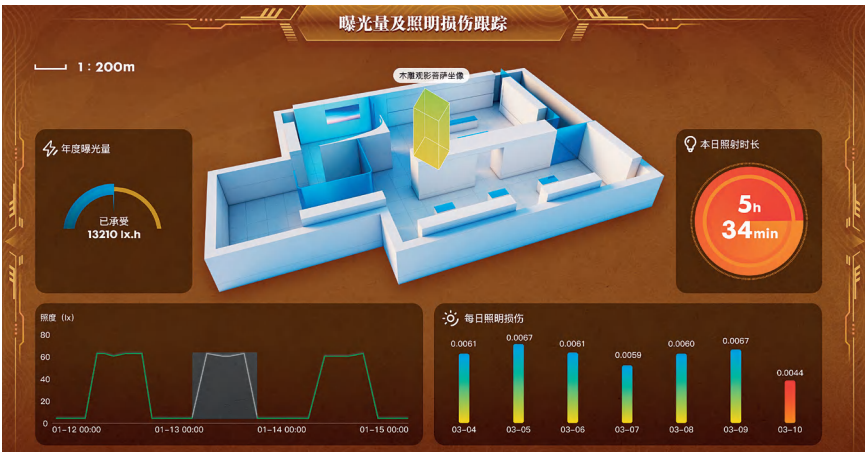
The "Three Shortcomings" of Environmental Monitoring Hindering the Cultural Heritage Sector

Current preventive conservation efforts in museum collections face three critical challenges. First, single-dimensional perception: monitoring systems capture only instantaneous values of temperature, humidity, and illumination, with insufficient spatial coverage. Equipment, artifacts, and spatial information remain disconnected, lacking intelligent analysis, resulting in delayed risk identification. Second, emphasis on monitoring over prediction: systems support only threshold-based alarms, without establishing dynamic trend prediction models. The absence of differentiated thresholds and early warning capabilities forces management into sustained passive response. Third, insufficient intelligent integration: multi-source correlation analysis models have not been established, and multidisciplinary knowledge reasoning engines are lacking. The system lacks adaptive learning capabilities and cannot achieve continuous optimization.

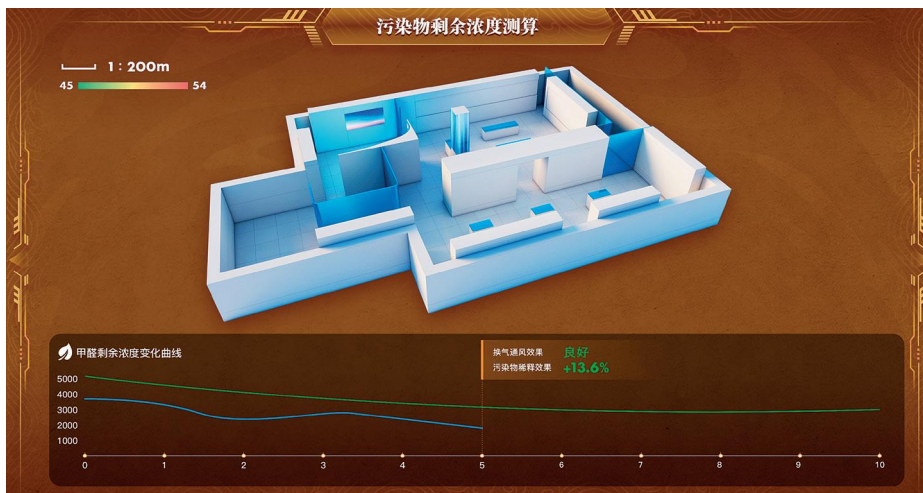
To address these industry-wide pain points, an integrated intelligent solution encompassing "monitoring - prediction - early warning - regulation" is urgently needed.

From Discrete Data to 3D Field Mapping: The Journey Toward Enhanced Environmental Perception

Following the principles of "demand-driven, phased implementation, iterative optimization, and smooth rollout," the project is advancing through five stages: completing spatial surveys of exhibition venues and planning grid-based sensor deployment, with graded protection protocols; deploying high-



Illumination Damage Assessment



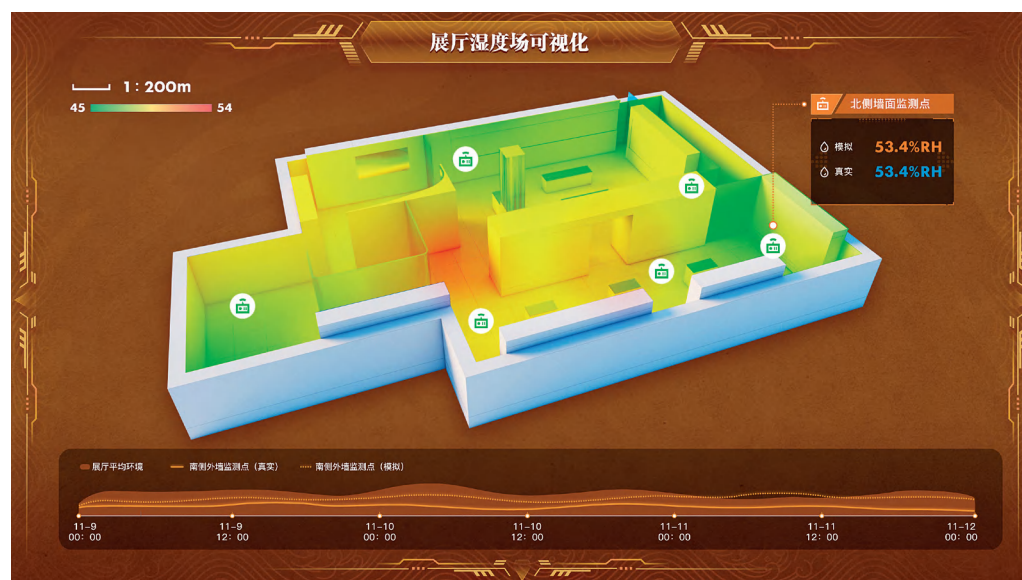
Pollutant Concentration Prediction

precision sensors and edge computing gateways, and establishing low-power wireless transmission networks; importing historical environmental data to train and calibrate three core algorithmic models — environmental field simulation, illumination damage assessment, and pollutant concentration modeling; launching the system for trial operation and establishing routine maintenance mechanisms; and advancing intellectual property protection and industry promotion.

The project has achieved three major breakthroughs. First, the shift from "point monitoring" to "field reconstruction": using environmental field simulation models powered by computational fluid dynamics and assimilation algorithms, the system generates continuous 3D field distribution maps from limited monitoring point data, supporting cross-sectional analysis and multi-zone correlation, accurately reconstructing spatial temperature and humidity distribution. Second, the shift from "qualitative judgment" to "quantitative assessment": an illumination damage assessment model has been developed, establishing coupling relationships between artifact materials and light intensity, spectral composition, and exposure duration, enabling quantitative calculation of damage levels and safe exposure times. A pollutant concentration simulation model, based on building material parameters, predicts diffusion trends to enable preemptive prevention. Third, the shift from "passive response" to "active prevention": through mathematical models of thermal and moisture fields, light environments, and pollutant diffusion, combined with real-time data for dynamic environmental trend prediction, the system intelligently regulates HVAC and dehumidification equipment, creating a full-cycle preservation paradigm of "prediction - early warning - regulation."

An "Invisible Protective Net" Behind Over 500,000 Artifacts

On the conservation front, the project has achieved a fundamental shift from "passive response" to "active prevention," collectively protecting over 500,000 artifacts (sets) and effectively extending their preservation lifespan. On the management front, it has replaced traditional manual monitoring and recording methods, reducing staffing requirements by over 40%, while the visualization platform and mobile remote control capabilities have significantly improved management efficiency. On the industry front, the project provides a practical, replicable intelligent preventive conservation model for the



Environmental Field Visualization

cultural heritage sector, advancing conservation philosophy and practice. On the social front, through environmental visualization displays and public education initiatives, it has enhanced public awareness of heritage conservation, contributing to the transmission and promotion of cultural heritage.

A Replicable Integrated "Monitoring–Prediction–Regulation" Paradigm

The project balances scholarly rigor with technological advancement, and is adaptable for cost-effective deployment across cultural heritage institutions of varying scales, offering broad potential for dissemination.

Standardized site survey and deployment protocols have been established, allowing flexible adjustment of deployment schemes according to venue size. The three core algorithms have been designed for lightweight reuse, requiring only adjustments to material and environmental parameters for adaptation to different venues. The integrated "monitoring – prediction – regulation" system is replicable across multiple scenarios including storage facilities, exhibition halls, and display cases. Over the next one to three years, the project will continue to advance technological iteration, optimize the three core algorithms, and achieve breakthroughs in damage quantification, precise prediction, and multi-source data fusion analysis. Patent applications and technical standardization will be pursued, with application scenarios extended to memorial halls, archives, and archaeological excavation sites. International cooperation and exchange will be promoted, contributing to the internationalization of technical standards.

On the risk prevention front, a comprehensive intellectual property management system will be established throughout the entire workflow, with robust patent and software copyright portfolios. Encryption technologies will be deployed to ensure data security, and emergency response mechanisms for data breaches will be put in place to guarantee secure and compliant system operation.

Innovative Practices in Digital Preservation and Research of Nanjing City Wall Cultural Heritage



Data collection and basic platform construction

Comprehensively empower digital protection and research work

Carry out research and assessment on "authenticity"

Deepen the research on the inscriptions on city bricks

Innovative Practices in Digital Preservation and Research of Nanjing City Wall Cultural Heritage

012

Applicant Institution

Nanjing City Wall Protection and Management Center

This case addresses the full lifecycle management of large-scale linear cultural heritage. Integrating technologies such as Geographic Information Systems (GIS), Building Information Modeling (BIM), the Internet of Things (IoT), big data, and 3D scanning, it has developed a "One-Map" resource management platform and a monitoring and early warning platform, establishing a smart management system that covers the entire 25.1 km of the city wall structure.

Confronting industry-wide challenges inherent to linear heritage — massive scale, irregular morphology, voluminous and complex information, and the absence of precedents for authenticity assessment in World Heritage nomination — the project follows a pathway of "full-site acquisition - standardized database - intelligent monitoring - research enablement," creating a replicable and scalable digital preservation paradigm for large-scale immovable cultural heritage.

The "Fourfold Challenge" of Linear Heritage

The Nanjing City Wall, with a surviving length of 25.1 km, is the world's longest and largest brick-and-stone city wall. It is currently leading the serial World Heritage nomination of the "City Walls of the Ming and Qing Dynasties in China." Its preservation and research face four critical challenges. First, the sheer scale of the physical structure: originally 35.267 km in length and 8 to 26 meters in height, with complex three-dimensional configurations, any digitization effort constitutes a project spanning tens of kilometers. Second, irregular geometric forms and diverse architectural structures: the wall's alignment follows local topography and features layered composite internal structures, posing significant technical challenges for digital modeling. Third, the unprecedented volume of spatiotemporal and quantitative data: the wall was originally constructed with more than 100 million bricks, many of which bear inscriptions recording their place of manufacture and responsible craftsmen or officials under the "wulei gongming" marking system, making data integration and application extremely difficult. Fourth, the lack of precedents for authenticity assessment in World Heritage nomination: no systematic assessment framework for wall-type heritage exists within China, necessitating the development of an evaluation system that aligns with international standards while remaining locally relevant, alongside a comprehensive digital solution.

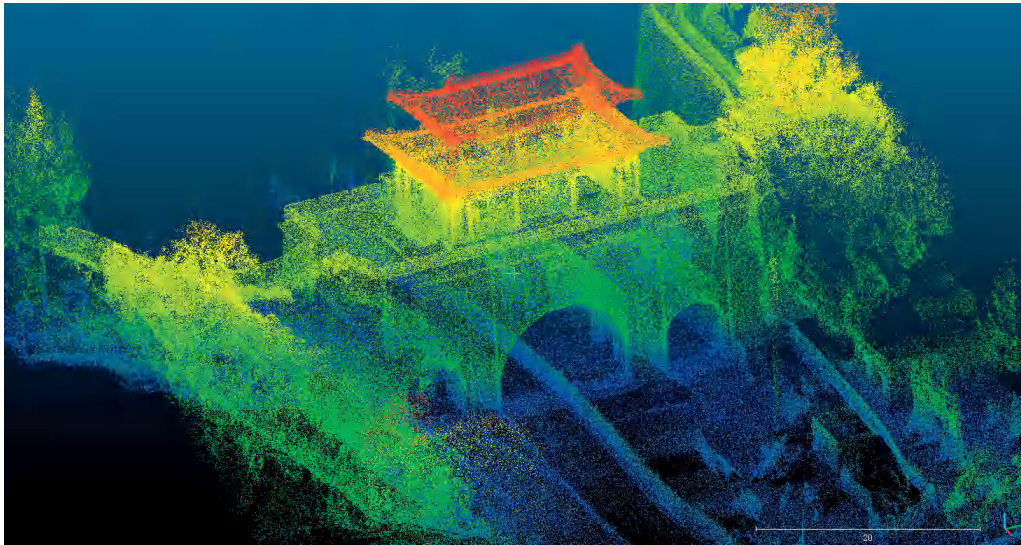
Bringing the 25 km Ancient City Wall to Life in Digital Space

Following the principles of "conservation first, demand-driven, and phased implementation," the project



"One-Map" Resource Management Platform

is advancing in two stages. During the data acquisition and foundational platform development stage, a "One-Map" resource management platform was built with GIS as the foundation and integrated with BIM, enabling 2D and 3D integrated visualization management and supporting full-feature functions including spatial queries, deterioration annotation, and project management. Leveraging IoT and communication technologies, 263 sets of automated monitoring devices were installed along the entire wall, covering 1,575 monitoring points across 19 categories and 61 indicators, forming a monitoring and early warning platform that enables round-the-clock heritage recording and alerting. During the comprehensive digital preservation and research enablement stage, the two platforms are deployed to carry out preventive conservation, authenticity assessment, and research on brick inscriptions.



"One-Map" Yifeng Gate Point Cloud Data

Practical innovations are embodied in three dimensions. On the technological front, multi-technology integration and synergy have been achieved, replacing traditional manual inspection and paper-based documentation. New technologies including integrated aerial-ground acquisition, deep BIM-GIS integration, and real-time digital twin mapping have been adopted, creating a high-fidelity digital representation of the entire 25.1 km city wall. Among these, the large-scale methodology combining quantitative surveying with qualitative heritage research for brick inscription documentation is considered a global first, and was awarded the First Prize of the Surveying and Mapping Science and Technology Progress Award by the Beijing Society of Surveying, Mapping and Geoinformation. On the management front, the project has achieved a leap from reactive response to proactive prevention. Through "One-Map" site-wide management, refined full-lifecycle management of the wall has been realized. The monitoring and early warning platform has transformed post-event emergency repairs into proactive risk management, enabling continuous monitoring of changes, early risk prediction, proactive risk mitigation, and preventive conservation. Structural inspections and 3D modeling of civil defense structures within the wall have been completed, earning the project the 2021 Outstanding Project Gold Award from the China Association for Geographic Information Industry. On the model front, the project has established a multi-stakeholder collaborative and sustainable ecosystem, shifting from government-only management to broader societal engagement. Digital tools have not

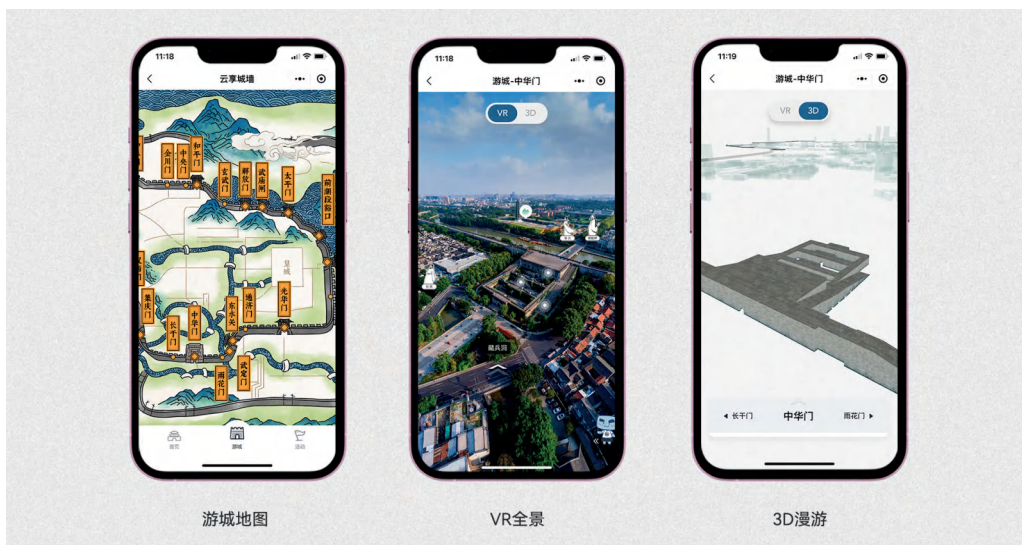
only reduced management costs but also enhanced cultural tourism value and creative revenue, generating a virtuous cycle of "preservation - utilization - reinvestment in preservation."

Digital Archives Safeguarding the Wall and Unlocking Cultural Tourism Value

On the conservation and research front, digital preservation now covers the entire 25.1 km wall structure. Since system deployment, over a thousand risks have been precisely identified. Using 3D laser scanning and archival documentation via the "One-Map" platform, authenticity assessment has been completed for approximately 1.4 km of the Qingliangmen section, providing crucial support for the World Heritage nomination. Over 170,000 clearly inscribed bricks have been captured with spatial coordinates and high-resolution imagery. A collaborative AI-based inscription recognition project with Nanjing Normal University received the Grand Prize at China's "Challenge Cup" competition.



Authenticity Assessment Fine Mapping of the City Wall Structure and Its Surroundings



"Enjoy the City Wall Online" Digital Exhibition & Interactive Platform

On the dissemination and industry front, the "Cloud Enjoy the Wall" platform has brought the 25.1 km wall to the cloud, enabling virtual 3D tours and cross-spatiotemporal sharing, and helping the museum achieve National First-Grade Museum status. Its exhibition received the Excellence Award in the China Museum Top Ten Exhibitions selection. In 2025, visitor numbers increased by 2.318 million compared to 2023, with average annual ticket revenue of approximately 60 million RMB over the past three years. Nearly 600,000 scattered wall bricks have been recovered. The project received the "Explorer Star" Award in the UNESCO Global World Heritage Education Innovation Case Competition.

From World Heritage Nomination Support to Industry Demonstration: The Nanjing Model Goes National

The project maintains a balanced focus on both practical needs and technological advancement, delivering a quantifiable and scalable digital solution for World Heritage nomination, scholarly research, and value interpretation of large-scale immovable cultural heritage.



Digital City Wall Smart Platform

The project is advancing through three iterative phases. By the first half of 2026, the "Digital Wall" smart platform will be completed, integrating five major functional modules. In the second half of 2026, full-line authenticity assessment will be conducted across nine core sections, introducing a quantitative authenticity index to support more systematic evaluation. From 2026 to 2030, the project will explore AI-based recognition of brick inscriptions and develop an inscription knowledge base. Key transferable lessons include: planning first — identifying core requirements before matching with appropriate technological solutions; data as the foundation — adhering to "full-site acquisition, unified standards, and shared development"; technology suitability — selecting proven technologies to ensure data and heritage security; and value extension — realizing an integrated "management-research-utilization-exhibition" approach that connects the entire chain of preservation and utilization. On the risk prevention front, the project prioritizes data and heritage security, strengthens intellectual property protection, and enhances institutional management frameworks.

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- Digital visualization
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HISTOGENES
Ferro-Ugric gene flow
in the Carpathian Basin

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- Digital archaeology
- Sustainability
- Inclusion
- Sharing knowledge



4. DH_BUDAPEST_2022 & DARIAH DAYS

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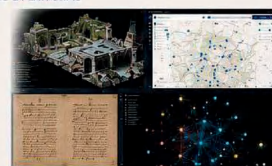
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- Workshops & training
- Networking
- Open innovation
- DARIAH community



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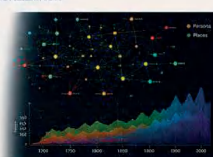
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- Digital preservation



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013

Digital Cultural Heritage at ELTE: An Integrated Framework for Archaeological Research, Aerial Archaeology Documentation, and Bioarchaeological Discovery

Applicant Institution

Eötvös Loránd University (ELTE)

Participating Institution

Hungarian Academy of Sciences (HUN-REN); Klapka György Museum of Komárom; DARIAH-EU and DARIAH-CEH; European Association of Archaeologists (EAA)

This case bridges digital cultural heritage and three core disciplines — archaeology, natural sciences, and digital humanities — to build an integrated research framework covering field archaeology, aerial archaeological documentation, and bioarchaeological discoveries. Building on nearly four centuries of academic heritage and over two hundred years of archaeological tradition, the project brings together 65,000 aerial archaeological images, excavation records from major sites including Brigetio, and bioarchaeological datasets such as ancient DNA and isotope analyses into a unified digital ecosystem. It forms a full-chain system from data acquisition and interdisciplinary analysis to public dissemination, offering a replicable comprehensive paradigm for digital cultural heritage development in universities worldwide.

An Integrated Solution to Industry-Wide Challenges

The cultural heritage field has yet to establish a unified integrated framework. The challenges are manifold: born-digital materials are stored in fragmented systems and are highly susceptible to technological obsolescence; archaeological data, museum collections, and scholarly literature belong to different systems, hindering cross-database analysis; the integration of archaeology and digital humanities remains shallow, with interdisciplinary potential not yet fully realized; the research scope extends from the Paleolithic to the Ottoman period, covering a geographic range from Europe to Central Asia, necessitating strong cultural compatibility of the platform; digital resources without continuous migration and updating may deteriorate faster than physical artifacts, yet no unified global preservation standard exists; and technologically advanced platforms with poor user interfaces significantly diminish their dissemination value.

In response, this project replaces fragmented toolkits with an integrated comprehensive system, achieving full-chain coverage from fieldwork to public engagement.

A Five-Tier Architecture Bridging Archaeology, Science, and Digital Humanities

The core innovation of this case lies in the development of a comprehensive research and education system that deeply integrates three major domains: traditional field archaeology, cutting-edge natural sciences, and digital humanities. All digital outputs are incorporated into a unified ecosystem from the design stage, with standardized metadata, persistent identifiers, and open-sharing protocols, fully complying with the FAIR data principles and European digital humanities infrastructure standards.

The system consists of five interconnected tiers. The field archaeology tier, based on sites including Brigetio, Bibracte, and Gellért Hill, ensures standardized collection of stratigraphic, image, and 3D data, with excavations at Brigetio spanning over thirty years. The aerial archaeology tier



Digital Cultural Heritage at ELTE: An Integrated Framework for Archaeological Research, Aerial Archaeology Documentation, and Bioarchaeological Discovery

transforms 65,000 historical aerial images into a public online database with geospatial indexing. The bioarchaeology tier integrates ancient DNA and isotope analysis findings through the HistoGenes project. The digital humanities tier, supported by the university's Department of Digital Humanities, provides database and semantic web tools. The public engagement tier supports undergraduate, graduate, and doctoral education while connecting with museums and international platforms. The project follows a standardized eight-step workflow: establishing research directions, designing collection protocols, data acquisition and quality control, data organization and integration, interdisciplinary analysis, results dissemination and sharing, educational outreach, and long-term preservation and format migration — ensuring standardized operation across the entire lifecycle.

Six-Dimensional Breakthroughs: From Disciplinary Integration to Global Leadership

The project has achieved six major breakthroughs. First, deep integration of three disciplines: systematic integration of field archaeology, advanced natural sciences, and digital humanities within a single university, enabling cross-disciplinary collaborative innovation. Second, transformation of legacy archives into public databases: over 65,000 aerial archaeological images accumulated over more than two decades have been upgraded from internal working archives to a public online database with geospatial indexing, providing a model for similar image heritage preservation worldwide. Third, internationalization and scaling of bioarchaeology: an international research consortium has been established through the HistoGenes European Research Council project, integrating ancient DNA, isotope analysis, and archaeological research, producing multiple internationally recognized research outcomes. Fourth, establishing a full-chain digital benchmark at a single site: the Brigetio Roman site integrates aerial survey, geophysical prospection, stratigraphic excavation, artifact research, and epigraphic study, with research results translated to the public through the visitor center. Fifth, strengthening collaboration within the European archaeological community: hosting the European Association of Archaeologists annual meeting in 2022, bringing together scholars from over sixty countries and demonstrating international influence. Sixth, establishing digital humanities as a long-



Digital Cultural Heritage at ELTE: An Integrated Framework for Archaeological Research, Aerial Archaeology Documentation, and Bioarchaeological Discovery

term institutional development direction: through the Department of Digital Humanities, the Hungarian National Digital Heritage Laboratory, and European international projects, digital cultural heritage has been established as a core institutional development priority.

A Three-Phase Strategy: From Local Practice to International Standards

The project is advancing through three phases: the first phase focuses on optimizing the aerial database and improving digital resource preservation systems; the second phase expands to include additional sites and educational programs; the third phase involves deep engagement in international standard-setting and the establishment of a globally comprehensive digital heritage research benchmark. Technological innovations include AI-empowered heritage research, the development of digital twins of archaeological sites, and the refinement of long-term preservation systems, with applications gradually expanding from Europe to the Near East and Central Asia.



Digital Cultural Heritage at ELTE: An Integrated Framework for Archaeological Research, Aerial Archaeology Documentation, and Bioarchaeological Discovery

Adhering to the three principles of disciplinary integration, open sharing, and standards-first, the project delivers a quantifiable and scalable systemic solution for digital cultural heritage development in universities worldwide. Transferable lessons include: a globally replicable curriculum system; a model for transforming aerial imagery into public databases applicable to peer institutions; an interdisciplinary integration approach that helps institutions overcome departmental silos; a pathway for international engagement through participation in European research infrastructure networks; and a proven "excavation - research - museum - dissemination" linkage mechanism for translating academic outcomes to broader audiences.

On the risk prevention front, the project has established long-term preservation systems for digital resources, including regular format migration and alignment with European digital humanities infrastructures, standardized international cooperation protocols, adherence to FAIR principles, modular architecture to accommodate technological iteration, and diversified funding sources.



014

An AIoT-Driven Digital Twin System for the Gandhara Civilization, Taxila Chapter

Applicant Institution

PISA (Pakistan Information Security Association)

Participating Institution

CIT (Center of Information Technology); IoT Center (Pvt) Ltd (Internet of Things)

This case weaves together artificial intelligence, the Internet of Things, 3D reconstruction, and archaeology to create a digital twin protection system for over 80 sites at Taxila, operating at the intersection of digital cultural heritage. As the capital of the Gandhara civilization and a UNESCO World Heritage site, Taxila embodies the unique convergence of Buddhist and Greek civilizations and is home to the oldest known university site. Yet it faces accelerated deterioration due to climate change, urban expansion, and looting.

Confronting the core challenges of traditional conservation — reactive response, fragmented information, and inability to predict degradation — the project establishes an intelligent closed loop of "sense - think - act," integrating aerial imagery, sensor data, and AI diagnostic models into a "single source of truth." This achieves a paradigm shift from static documentation to predictive conservation, offering a replicable AI-driven solution for the protection of endangered stone cultural heritage worldwide.

The Triple Crisis Facing the Site

The conservation of the Taxila archaeological site is caught in a web of intersecting crises. First, environmental and atmospheric damage: the region experiences extreme seasonal climates, with heatwaves alternating with heavy rainfall. Gandharan architecture, is predominantly constructed of porous schist and limestone, experiences surface exfoliation due to continuous thermal expansion and contraction and continuous thermal expansion and contraction cause surface exfoliation. Rising humidity promotes the growth of lichens and mosses, which invade micro-cracks and exert biophysical pressure, compromising the integrity of walls and stupa foundations. Second, urbanization and illegal encroachment: Taxila is not an isolated desert site but a "living landscape." Cities and villages are expanding at an alarming rate, with illegal development taking place directly on unexcavated sites. Agricultural land acquisition frequently results in the destruction of small, unrecorded Buddhist sites before they can receive official protection. Third, ongoing looting: Gandharan schist reliefs are highly sought after on the international black market. Fragmented friezes are constantly being chiseled away from their original contexts, resulting in leading to an irreversible loss of contextual integrity. Fourth, structural deficiencies in traditional conservation approaches: current conservation efforts are largely reactive — intervention occurs only after wall collapse, by which time it is too late. Hand-drawn maps and 2D photographs cannot capture three-dimensional stress or rates of degradation, and the absence of high-resolution time-series data makes risk prediction impossible.

In response, the industry urgently needs a digital solution that combines real-time monitoring with predictive simulation capabilities.

An AI-Driven Digital Twin System: From Documentation to Simulation

The core breakthrough of this case lies in the development of an AI-driven digital twin system, rather than a conventional 3D model. The system employs a three-tier architecture of "sense - think - act." The sense layer deploys IoT sensors to collect real-time micro-environmental data including temperature, humidity, and vibration. The think layer utilizes a convolutional neural network customized for schist and limestone to automatically identify surface erosion and crack propagation, achieving a 90% confidence level in degradation diagnosis. The act layer supports the simulation of conservation interventions within the digital model, preventing subjective misjudgment. The system also incorporates a generative reconstruction module built on generative adversarial networks, capable of "completing" the original appearance of damaged friezes based on surviving fragments and historical imagery.

Four core innovations are driving industry breakthroughs. The first is the functional leap from documentation to simulation: the system not only records the current state but also predicts future degradation trends based on climatic factor inputs, enabling the design of protective shelters before deterioration occurs. The second is AI-powered "silent guardians": automating structural health

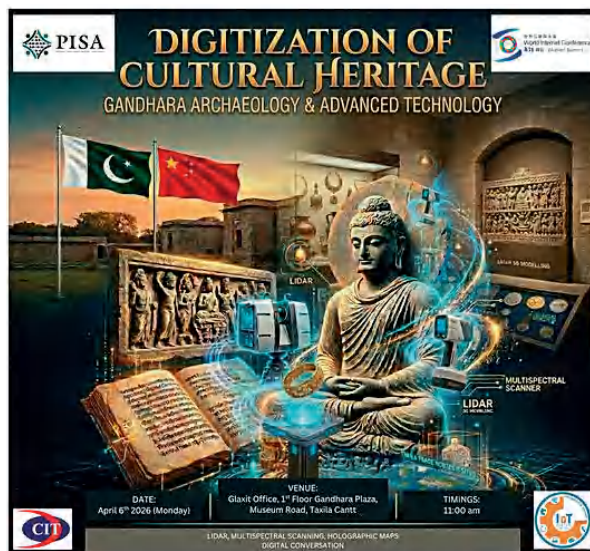


Demonstration on "How digital solution is required to preserve Gandhara Civilization?"

monitoring with the potential for full-site scalability. The third is virtual repatriation: a "digital DNA" ledger marks the original location of each artifact, providing tamper-proof legal evidence for the cross-border recovery of looted objects. The fourth is modular twin templates: the architecture is adaptable not only to schist structures but also to brick-built sites such as Mohenjo-daro and to grotto complexes along the Silk Road.

From Environmental Monitoring to Artifact Diagnosis: A Complete Conservation Loop

The project has completed testing and simulation validation. [Test Simulation Output 1] demonstrates the AI-driven virtual presentation capability — a neural rendering engine transforms geospatial and image data into an "AI perspective," enabling seamless switching between site-wide aerial views and detailed ground-level study. This allows global users to explore remote monasteries in high definition,



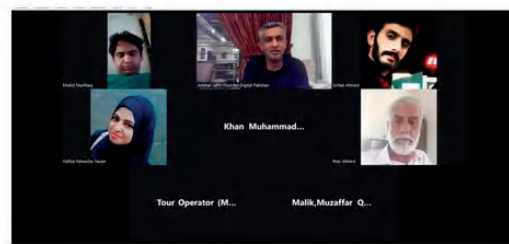
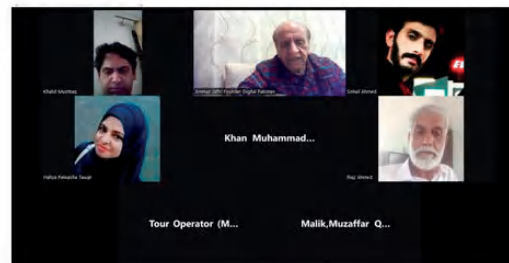
Site visit to demonstrate "Digitization of Cultural Heritage."

overcoming physical access limitations. [Test Simulation Output 2] validates the three core modules of the Heritage Nexus platform: the dashboard displays real-time key indicators — temperature 36.6° C, relative humidity 51.8%, and vibration levels — supporting 24/7 anomaly detection; the upload and preservation module creates digital replicas of artifacts from high-resolution imagery; and the damage identification AI automatically detects surface erosion with 90% confidence and triggers intervention alerts. The platform features a trilingual interface in Chinese, English, and Urdu, preliminarily validating a complete conservation loop from environmental monitoring to artifact diagnosis.

A Three-Phase Roadmap and Four Globally Transferable Lessons

The project is advancing through three phases: within the first year, preliminary 3D scanning, AI model training, and laboratory validation will be completed; from year one to year two, IoT networks will be deployed and neural rendering engines and educational content will be developed; from year two onward, global release and predictive modeling will go live.

Adhering to the principle that technology assists rather than replaces human judgment, the project delivers a quantifiable and replicable AI-driven solution for the protection of endangered stone cultural



Online awareness session for technologists & archaeologists

heritage worldwide. Its transferable lessons include: the digital DNA ledger sets a new benchmark for international legal practice in artifact repatriation; the modular twin template can be rapidly adapted to various endangered heritage types; the open-participation model for building digital communities demonstrates that digital experiences are a powerful tool for fostering local support for conservation; and the economic logic of prioritizing preventive conservation shows that the cost of AI-based early diagnosis is far lower than that of late-stage physical restoration, providing a sustainable financial model for site management.

A Five-Layer Defense Framework for Secure and Trustworthy AI-Driven Heritage Conservation

On the risk prevention front, weather-resistant hardware and edge computing are deployed to address data reliability challenges in extreme environments; expert review mechanisms are established to prevent AI-generated misrepresentations; strong encryption technologies protect sensitive geographic data; cultural and religious experts are engaged to ensure that digital rebirth respects the sacredness of Gandharan civilization; and a diversified financing system, combined with the economic benefits of preventive maintenance, ensures the long-term sustainability of operations.



Future collaboration and suggestions on how to work on unexplored Gandhara civilization sites and its digitization?

德格印经院珍稀雕版数字化保护项目



Digital Preservation Project for Precious Woodblocks of Dege Parkhang

015

Applicant Institution

China National Archives of Publications and Culture (Hangzhou)

Participating Institution

Dege County Institute of Cultural Relics and Archaeology

This case centers on the emergency conservation and digital archival development of rare woodblocks in ethnic minority regions, integrating non-contact 3D scanning, high-precision planar imaging, and multispectral information acquisition to build an integrated "end - cloud - application" system.

Jointly implemented by the Hangzhou Branch of the National Archives of Publications and Culture and the Dege County Institute of Cultural Relics and Archaeology, the project addresses three major challenges confronting the Dege Sutra Printing Academy's collection of over 330,000 Tibetan woodblocks (two-thirds of which are rare ancient editions): fragile preservation environments, limitations of traditional documentation methods, and the acute tension between utilization and conservation. Adopting a strategy of "pilot first, phased advancement, full coverage," the project has established permanent digital archives with millimeter-level precision, creating a replicable paradigm for the digitization of rare documents in ethnic minority regions.

The Three Crises Facing Woodblocks Under the Snow Mountains

Founded in 1729, the Dege Sutra Printing Academy is renowned as the "Tibetan Cultural Treasury Under the Snow Mountains." It was inscribed on the UNESCO Intangible Cultural Heritage List in 2009 and the UNESCO Memory of the World Regional Register for Asia and the Pacific in 2024. The conservation of its woodblocks faces three critical challenges. First, the fragile physical preservation environment: Dege is situated in a high-altitude region with an arid and variable climate, making wooden blocks susceptible to cracking, deformation, and insect infestation. The Academy is open to the public, and visitors can directly touch the blocks, posing risks of physical damage. Second, the limitations of traditional documentation: historical records of the blocks have relied heavily on the memory and oral transmission of custodians, with no comprehensive catalog available for consultation. Moreover, traditional methods cannot fully capture the morphology, carving textures, or micro-level deterioration of the blocks. If the physical blocks are damaged, an irreversible cultural loss would ensue. Third, the acute tension between utilization and conservation: as an active printing site of living heritage, frequent printing accelerates the wear of ancient blocks, while complete closure for protection would restrict academic research and public dissemination. The sector urgently needs a solution that can achieve both "permanent preservation" and "unlimited accessibility".

How the "End-Cloud-Application" Technical System Brings Woodblocks to Life

The project has constructed a core "end - cloud - application" technical architecture. At the acquisition end, standard color-temperature cold light sources and non-contact 3D laser scanning are employed,



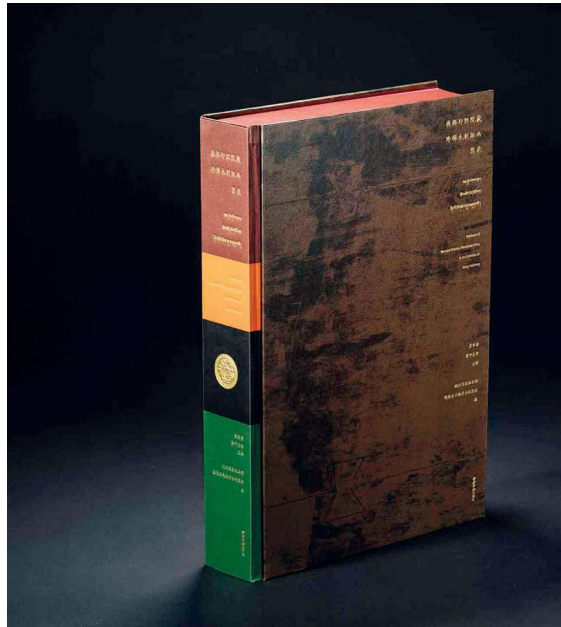
combined with high-precision planar imaging and multispectral information acquisition, forming a multi-dimensional data capture system of "3D geometry + 2D texture + multispectral information" — ensuring no contact with or movement of the artifacts throughout the process. At the processing end, a high-performance data processing platform is established, employing denoising, stitching, texture mapping, and color

correction algorithms to construct high-fidelity digital models. At the application end, a rare woodblock data archive is created, supporting digital rubbing generation, virtual display, and academic research access, forming a closed-loop digital asset system.

The project is being implemented in three phases. During the preparatory and initiation phase (July 2023 - July 2024), the Dege County People's Government and the Hangzhou Branch of the National Archives of Publications and Culture signed a cooperation agreement, adopting a "point-to-area" strategy with rare ancient prints as the pilot. During the full-scale acquisition phase (August 2024 - January 2025), the team conducted parallel non-contact 3D scanning of the physical blocks and high-definition imaging of their printed impressions. During the data processing and archiving phase (January 2025 - March 2025), data denoising, stitching, optimization, and 3D modeling were completed, and a specialized team was organized to carry out Chinese naming and translation of the blocks, establishing a comprehensive catalog archive.

Millimeter-Level Precision and Data-Driven Preventive Conservation

The project has achieved three major innovations. First, millimeter-level precision permanent archiving: scanning accuracy error ≤ 0.01 mm, point cloud noise $\leq 15\%$, and 3D volumetric accuracy of $0.015 + 0.035$ mm/m — not only restoring textural details but also establishing a quantifiable geometric baseline. Second, data-driven preventive conservation: a monitoring mechanism has been pioneered that uses the initial scanning data as the "time zero" reference. Through periodic re-scanning, deformation heat maps are automatically generated, enabling millimeter-level early warning of deterioration progression, upgrading conservation decisions from "experience-based estimation" to "data-driven scientific diagnosis." Third, digital rubbing technology: based on the 3D models, digital rubbings are simulated, eliminating the need for physical contact with the artifacts and thus avoiding potential damage.



Digital "Immortality" and the Dual Value of Cultural Assistance to Sichuan

The project has completed the full-chain digitization of ancient printed woodblocks. All models have achieved millimeter-level precision (error ≤ 0.01 mm), with high-fidelity color reproduction in planar imaging and noise controlled within 15%. The first permanent digital archive has been established. In collaboration, the Catalogue of Rare Woodcut Prints from the Dege Sutra Printing Academy has been published, featuring 300 rare ancient prints with an innovative "left-block, right-print" comparative display format.



On the conservation front, digital "immortality" has been achieved, ensuring that the form and texture of the blocks are permanently preserved even if the physical objects are damaged. On the research front, the project has filled the gap in digital resources, providing primary materials for the study of Han-Tibetan cultural exchange history and printing techniques. On the dissemination front, as a model of "cultural assistance to Sichuan," the project has deepened Zhejiang-Sichuan interaction and transcended geographical limitations. On the industry front, it has set a new benchmark for the digitization of fragile wooden cultural objects.

From 330,000 Woodblocks to a Long-Term Path for Global Sharing

The project adheres to the principles of conservation first, standards first, and open sharing, providing a replicable solution for the digitization of rare documents in ethnic minority regions. Its core transferable lessons include: adhering to the "in situ non-destructive" principle to minimize the risk of artifact movement; establishing "inter-institutional collaboration" mechanisms that integrate national-



level technical resources with local support capabilities; and implementing a "standards-first" strategy by standardizing data formats and naming systems from the outset of acquisition, ensuring the long-term usability of digital assets.

The project has developed a long-term roadmap: from 2025 to 2030, the remaining woodblocks will be digitized in a phased and categorized manner, establishing full-coverage archives for all over 330,000 blocks; from 2026 to 2028, Zhejiang-Sichuan academic resource integration will be deepened, advancing research on intangible heritage such as Tibetan paper and ink manuals. In addition, the project will develop immersive exhibitions and VR/AR experiences, and promote the integration of digital resources into global sharing platforms. On the risk prevention front, digital watermarking and blockchain-based rights verification will be employed with tiered access controls; dedicated funding will be secured and diverse financing channels explored; and interdisciplinary talent will be cultivated through university partnerships.



Torino

Elenco musei



Capo Colonna



MuNDA - Museo Nazionale d'Abruzzo



Torino



Aquileia



016

DHGP-Digital Heritage Gateway Platform of the Italian Ministry of Culture

Applicant Institution

Directorate General of Museums, Italian Ministry of Culture

This case belongs to the field of museum heritage digitization and national-level immersive virtual experiences for cultural heritage, with a focus on developing a federated multi-tenant platform that provides a unified access point for diverse museum networks.

The Digital Heritage Gateway Platform (DHGP) is Italy's national 3D immersive virtual experience platform for museum heritage. Developed by the Directorate General of Museums of the Italian Ministry of Culture and funded through the National Recovery and Resilience Plan, it integrates resources from 12 national museums and is now fully operational. It is also Italy's first national immersive virtual museum network deployed on the national sovereign cloud with a federated architecture.

The Digital Challenges Facing Nearly 500 Cultural Venues

Italy's public museum system comprises over 480 cultural venues, with collections and exhibitions of profound historical, artistic, and typological richness. However, digital services have long been fragmented — online collection catalogues follow different standards, virtual tour technologies vary, visual identities are inconsistent, and content management systems operate independently, resulting in a fragmented digital experience. Globally, mature projects such as the Digital Palace Museum in China and the Rijksmuseum's online platform in the Netherlands have all established comprehensive national-level digital systems, making Italy's shortcomings increasingly apparent.

This project aims to address a series of interrelated challenges: incompatible technical solutions across museums, leading to uneven quality of virtual tours; the absence of a unified national technical workflow for high-precision 3D acquisition and web optimization, resulting in duplicated investments; the "one museum, one platform" model's inability to balance individual museums' content autonomy with a consistent network-wide user experience; and the lack of a national digital window for international audiences, limiting Italy's voice in the global field of cultural heritage digitization.

How the Multi-Tenant Architecture Balances Unity and Autonomy

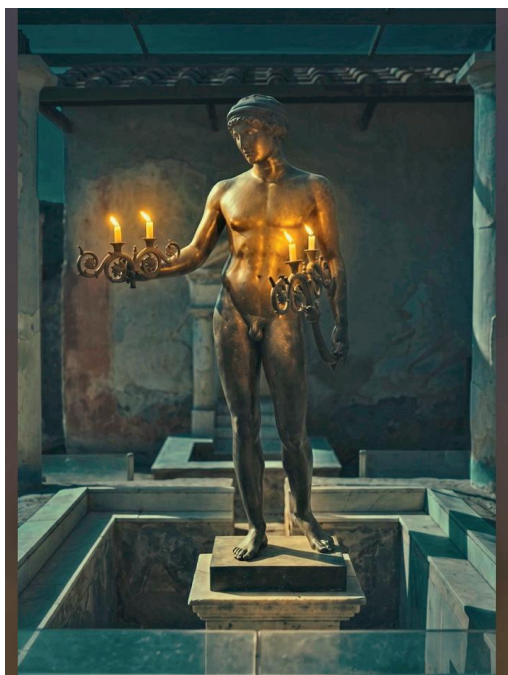
The platform adopts a cloud-native federated multi-tenant architecture with three clearly defined and independently upgradeable layers. The content layer allows each museum to independently manage artifact selection, narrative design, and multilingual translation, fully preserving editorial autonomy. The presentation layer is centrally managed to ensure consistent visual style and user experience across the network. The infrastructure layer is deployed on Italy's National Strategic Cloud Platform, meeting security, operations, and digital sovereignty requirements. New museums can be onboarded without modifying existing systems, effectively controlling marginal expansion costs.

The platform fully implements accessibility design, achieving AA-level web accessibility compliance and offering bilingual services in Italian and English. Open standards are adopted: 3D models use the glTF format, high-resolution images follow the IIIF framework, and metadata complies with FAIR principles, ensuring interoperability with Europeana and global platforms.

The project's core innovations are reflected in four aspects. First, the adoption of a multi-tenant architecture breaks with the traditional "one museum, one platform" model, making platform expansion more gradual and controllable. Second, it integrates high-precision 3D surveying, web-optimized presentation, and full-spectrum accessibility services, with open standards ensuring international interoperability. Third, it designs independent digital narrative pathways around virtual exhibition spaces, complementing physical visits. Fourth, its deployment on the national sovereign cloud makes it a key pillar of Italy's digital cultural sovereignty.



12 Museums Online in One Year: The "Italian Speed" of Delivery



Digital reconstruction outcomes of the Ephebe statue — Leveraging the DHGP platform, the Pompeian artefact was reconstructed in 3D and virtually recontextualized within the original domus where it was discovered.

In less than one year of actual implementation, 12 museums were fully launched, covering seven Italian regions. These include the Museum of Roman Civilization, the National Etruscan Museum of Villa Giulia, the Royal Museums of Turin, and the National Archaeological Museum of Aquileia. The platform is also deeply integrated with Italy's national museum visitor services portal and the national cultural heritage cataloguing system, reflecting the Ministry of Culture's overarching vision of using museum digitization to build digital cultural sovereignty.

Four Transferable Lessons and a Three-Phase Roadmap

Adhering to the principles of open architecture, interoperable standards, and inclusive sharing, the project offers a replicable solution for the development of national-level virtual museum networks worldwide. Its core transferable lessons include: a federated multi-tenant architecture

that balances unified user experience with institutional autonomy; open and interoperable standards ensuring long-term compatibility; national sovereign cloud deployment providing a secure and controllable foundation; and accessible, inclusive design making cultural heritage resources available to all.

The platform is advancing through three phases. Phase I focuses on consolidating the operations of the existing 12 museums and refining monitoring and feedback mechanisms. Phase II will onboard additional museums and introduce features such as VR walkthroughs, AI-guided tours, and cross-institutional thematic itineraries. Phase III will involve participation in European cultural heritage digitization projects and international standard-setting to establish a global benchmark, while progressively opening digital resources to Europeana and launching international collaborative digitization projects centered on themes such as the Silk Road.

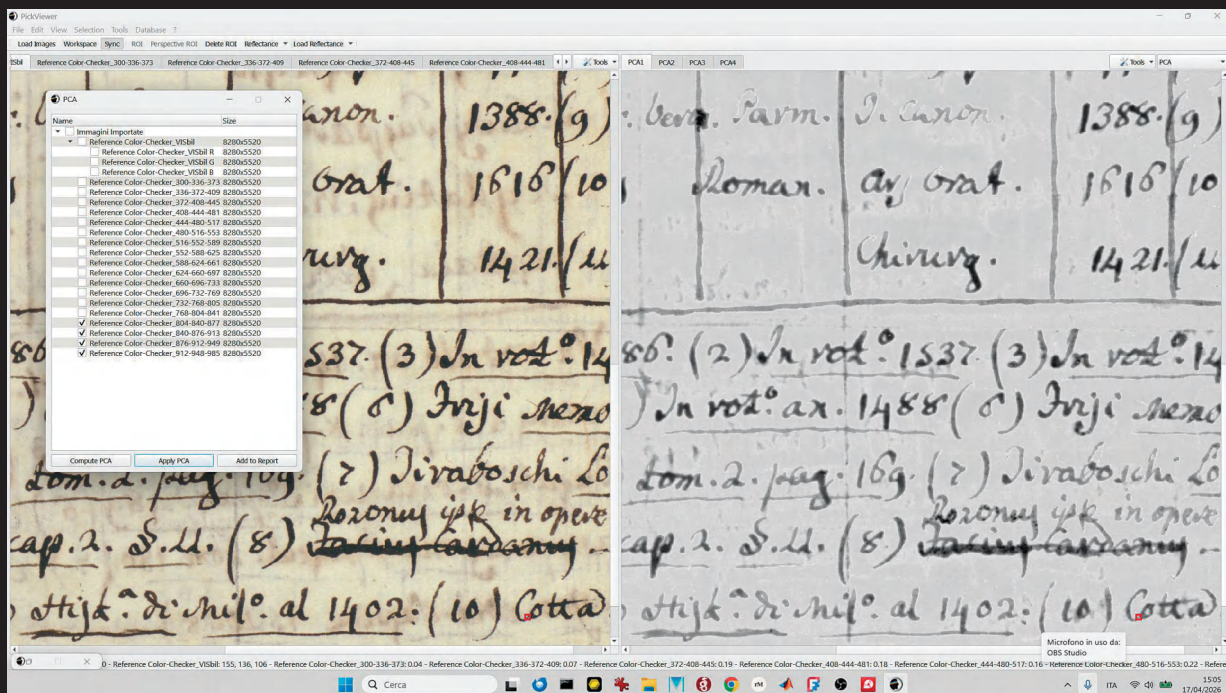


Left: Immersive underwater digital reconstruction outcomes of the sculptural group from the Grotta Azzurra (Blue Grotto) by Archaeological Museum of Capri— Leveraging the DHGP platform, the Roman- era sculptural group excavated from the Blue Grotto was reconstructed in 3D and virtually recontextualized within its original underwater environment.

Middle: Digital reconstruction outcomes of the Temple of Apollo at the Veii Archaeological Park — Leveraging the DHGP platform, the temple architecture was reconstructed in 3D, and the statues of the gods Apollo and Heracles — now housed in the National Etruscan Museum in Rome — were virtually restored to their original positions.

Right: Dynamic presentation outcomes of the painted pottery depicting the goddess Demeter by the National Archaeological Museum of Siritide, Policoro—Leveraging the DHGP platform, the static painted imagery of the agricultural goddess Demeter on the vase was animated to present the artistic and mythological significance of ancient Greek vase painting through dynamic narrative.

On the risk response front, to address potential resistance from new venues, the existing 12 museums will serve as a validation of the multi-tenant model's viability, alleviating concerns for future participants. On the technological front, the adoption of international open standards will prevent vendor lock-in and reduce iteration costs. On the sustainability front, the platform will be embedded into the Ministry's broader heritage digitization strategic framework, while actively participating in various European funding programs to diversify funding channels.



Principal Component Analysis (PCA) results based on infrared spectral data

017

Analysis of 14th and 18th century Ancient Manuscripts with Highly Accurate Hypercolorimetric Multispectral Imaging

Applicant Institution

Profilocore Srl

Participating Institution

University of Pavia, Italy

This case focuses on the non-invasive identification and degradation detection of inks in historical manuscripts and written materials. Employing the hypercolorimetric multispectral imaging (HMI) system independently developed by Profilocore Srl, the project captures high-precision colorimetric and spectral reflectance data across the 300 – 1000 nm wavelength range. Combined with comprehensive mathematical methods including Principal Component Analysis (PCA), cluster analysis, and spectral database comparison, it enables precise differentiation of ink formulations, extraction of subsurface hidden information, and detection of early-stage degradation signs, providing a quantifiable and reproducible scientific diagnostic tool for the conservation and restoration of historical manuscripts.

Ink Identification: A "Technical Blind Spot" in Manuscript Conservation

Accurate identification of inks in historical manuscripts and written materials has long been a challenge in both heritage conservation and philological research. First, traditional point-analysis techniques are limited by the number and location of sampling points, making it difficult to comprehensively characterize ink distribution across an entire page, while visual inspection under standard photography is virtually ineffective when faced with visually similar ink formulations. Second, the identification of erased or otherwise hidden texts presents an even greater challenge. Third, inks are highly susceptible to damage from ultraviolet radiation, humidity fluctuations, abrasion, chemical factors, and biological agents—even minor degradation can lead to loss of legibility and, in some cases, permanent loss of textual information. Fourth, traditional multispectral imaging has long remained at the level of uncalibrated false-color composites, with results varying significantly across operators. This approach cannot support fine material classification or time-series monitoring, and it is incapable of promoting the standardization of methods and databases.

In response, the industry urgently needs a high-precision, repeatable, and non-invasive diagnostic solution to facilitate the transition from experience-based judgment to data-driven scientific assessment.

Acquisition-Calibration-Analysis: A Full-Chain Technical Architecture Addressing Diagnostic Challenges

The hypercolorimetric multispectral imaging system developed by Profilocolore Srl establishes an integrated "acquisition - calibration - analysis" workflow.

At the calibration end, the AI-powered SpectraPick software performs calibration, outputting CIELAB images with an accuracy of $dE_{2000} < 2$, monochromatic images with spectral reflectance accuracy of up to 98% across the 300 - 1000 nm range, and user-defined virtual filter channels.

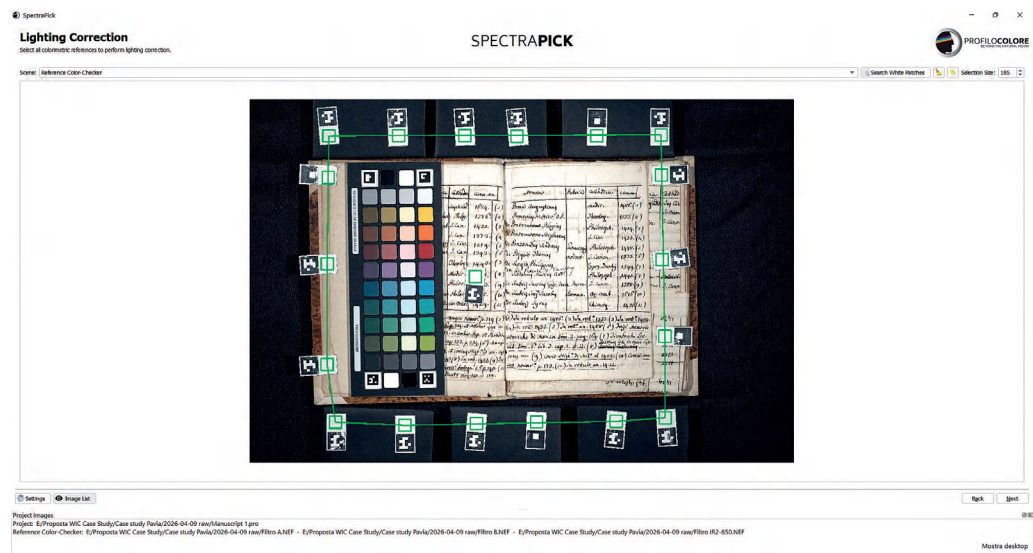


Image acquisition process

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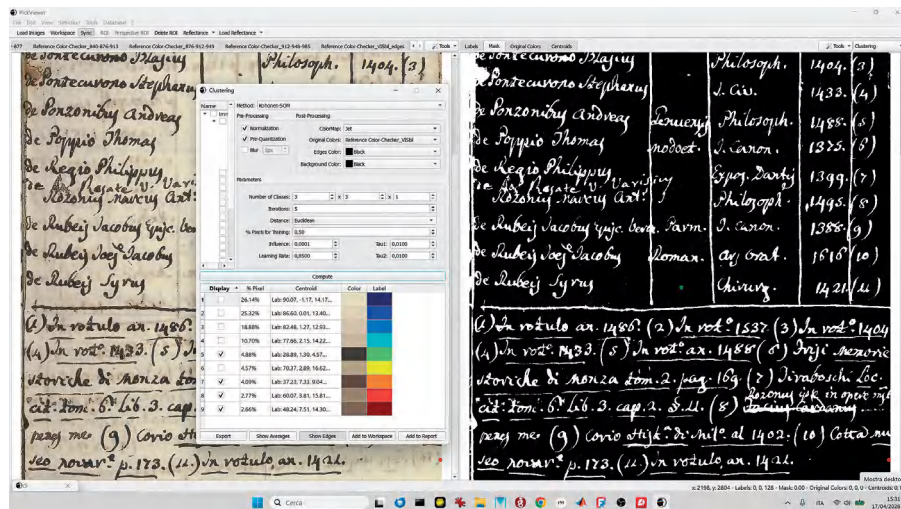
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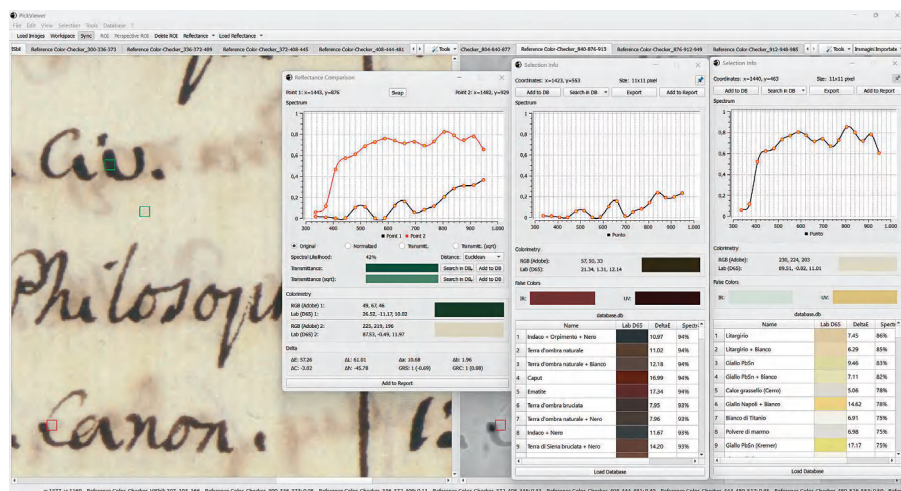
Marker in spectrapick

At the analysis end, PickViewer provides an integrated environment supporting PCA, neural mapping, spectral database comparison, and fusion analysis with third-party techniques including XRF, Raman spectroscopy, and FTIR, automatically generating standardized diagnostic reports.

The system features seven key attributes: portability, precision, speed, flexibility, ease of use, standardization, and cost-effectiveness. Its core technological breakthroughs include: full-spectrum sensitivity revealing spectral differences invisible to the naked eye; near-infrared and ultraviolet fluorescence penetrating surface layers to reveal subsurface anomalies and hidden texts; high-resolution multi-band fusion combined with PCA and clustering to separate multi-layer optical contributions; CIE-based colorimetric calibration establishing reference spectral databases and enabling pixel-level time-series comparison; rapid acquisition and automated processing capturing and aligning all bands within seconds with automatic calibration; AI-driven software supporting cross-batch measurement data integration to build material knowledge bases; and special algorithms based on AI and scattering characteristics for identifying individual pigment components within mixed colors.



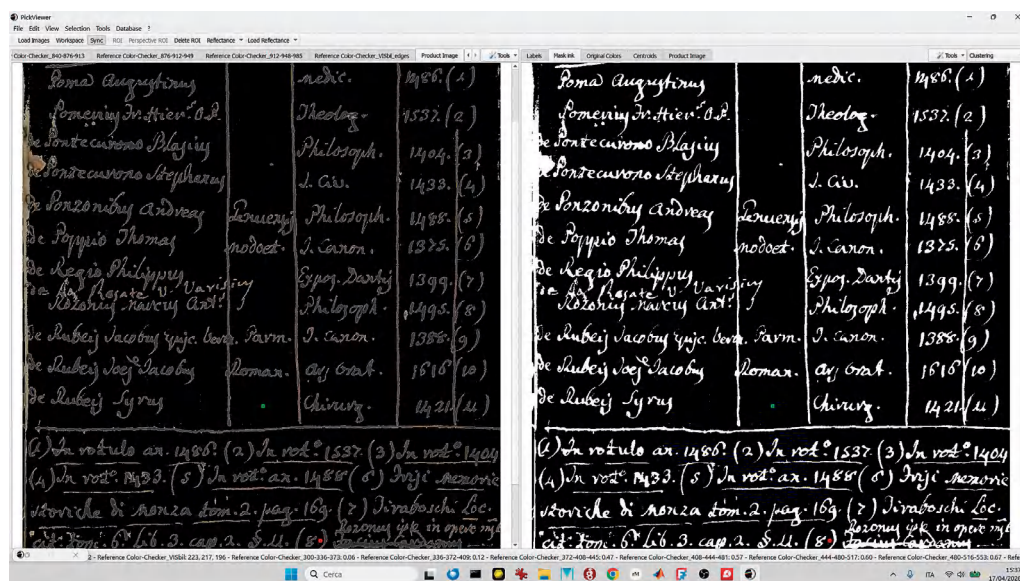
Ink selection by clustering



Paper vs ink spectra

From the Vatican to the Louvre: A Common Choice of Leading International Heritage Institutions

The system has been deployed in multiple international cultural heritage conservation projects, serving clients including the Vatican Museums and the Louvre. Research findings demonstrate that multi-spectral band fusion significantly enhances the differentiation of visually similar inks, effectively identifying subsurface anomalies even in cases where texts have been erased, faded, or rendered illegible by chemical degradation. Calibrated colorimetric and spectral data are comparable across time, enabling the establishment of consistent condition reports and serving as digital twins of written materials, offering a promising direction for future HMI material diagnostic research.



Masked ink

Five Technology Iteration Directions

Adhering to the three principles of high precision, standardization, and open integration, the project delivers quantifiable and reproducible scientific tools and solutions for the non-invasive identification and diagnosis of inks in historical written materials.

Its core transferable lessons include: ensuring cross-time, cross-operator, and cross-device data comparability through standardization and repeatability; supporting integrated analysis of multiple technical data sources through an open, multi-technology fusion architecture; extending laboratory-grade precision to field operations while maintaining ease of use comparable to conventional photographic equipment; and reducing dependence on operator expertise and minimizing human bias through AI-driven workflows.

The project's technology iteration roadmap is clearly defined: integrating 2D and 3D terahertz technologies to enhance surface roughness and depth analysis; incorporating thermographic imaging to study material thermodynamics and stratigraphic information; leveraging robotic automation for precise positioning to further improve diagnostic quality; exploring cutting-edge applications of

metamaterials and metasurfaces in heritage diagnostics; and extending system capabilities to cloud and mobile applications for remote access and operation.

On the risk prevention front, international standard formats will be adopted to ensure long-term data availability, independent of any proprietary format or single vendor. Systematic training programs will be implemented to help users rapidly master operational protocols. Continued R&D investment and a clear technology iteration roadmap will ensure the system's long-term competitiveness.

文物指纹

Cultural Relic Fingerprint

基于微痕比对的藏品管理应用

Collection Management Application Based on Micro-trace Comparison

AI图像识别 || 文物智慧安全监管 || 文物身份鉴别

AI image recognition || smart security supervision of cultural relics || cultural relic identification



杭州市临平博物馆
HANGZHOU LINPING MUSEUM

018

Cultural Relic Fingerprint: Collection Management Application Based on Micro-trace Comparison

Applicant Institution

Hangzhou Linping Museum

This case focuses on the challenge of identity authentication for movable cultural relics in circulation. Integrating high-precision micro-traces acquisition hardware, AI-based image matching algorithms, and blockchain certification technology, it has established an identity verification system that uses the surface micro-traces of cultural relics as unique "fingerprints."

Jointly developed and implemented by the Hangzhou Linping Museum and a technology company, the project addresses critical pain points in relic identity verification — low efficiency, weak anti-counterfeiting capabilities, and difficulties in accountability — amid increasingly frequent inter-museum exchanges. Following the technical pathway of "relics as the subject, micro-traces as the key," the project has achieved a transition from "human-reliance" to "technology-led" verification, offering a replicable solution for the intelligent supervision of cultural relics throughout their circulation lifecycle.

The "Counterfeit Substitution" Risk in Relic Identity Authentication

As the museum sector enters a stage of high-quality development, inter-museum exchanges are becoming more frequent, and the volume of relic check-in, check-out, loans, and inventory checks has risen sharply. At the same time, the techniques used to produce counterfeit relics have become increasingly sophisticated, reaching levels of realism beyond the capacity of human visual inspection. Although some museums have introduced digital technologies such as RFID tags, these measures remain essentially digital extensions of traditional management processes and have yet to fundamentally resolve the issue of unique, non-destructive, and tamper-proof identity authentication based on the relic itself. RFID tags are not applied directly to the relics themselves but remain a form of detached "object-and-tag" management. In the event of a counterfeit substitution, post-incident investigation and accountability become extremely difficult.

In response, the industry urgently needs an identity authentication solution that operates directly on the relic itself, requires no attached tags, enables verification at any time, and is inherently unforgeable.

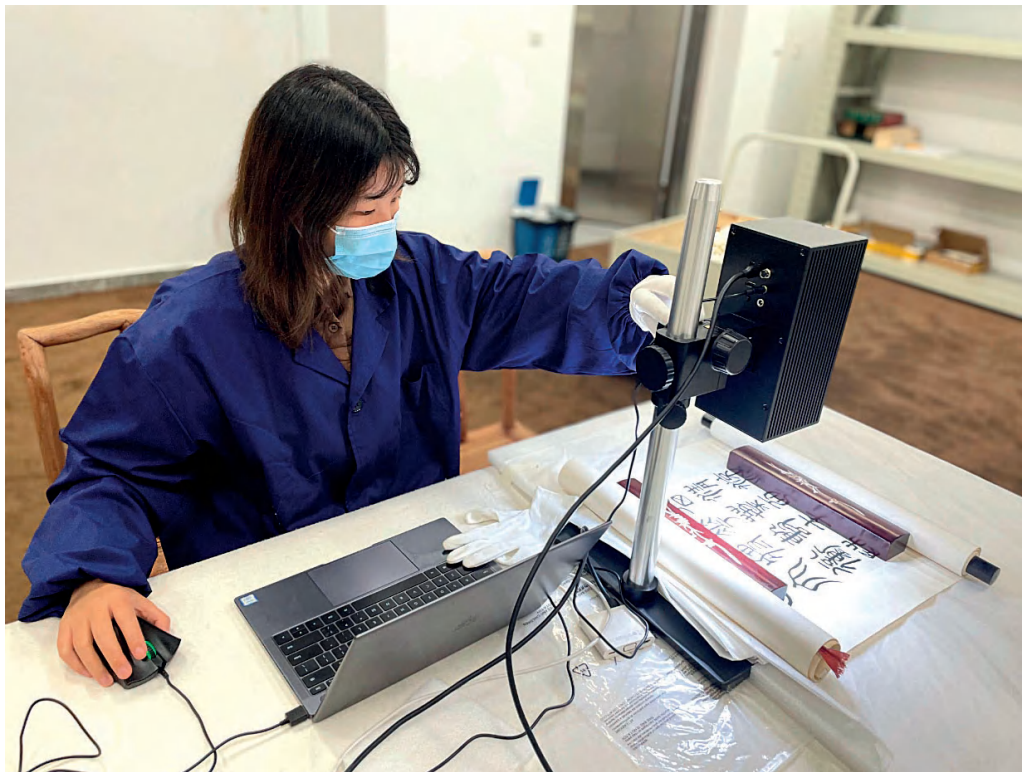


Specialized equipment for cultural relic fingerprint acquisition and comparison

The Threefold Technical Loop of Micro-Traces Acquisition, AI Matching, and Blockchain Certification

The project has established a technical pathway centered on "relics as the subject, micro-traces as the key," building a comprehensive solution through three core technologies.

Specialized hardware acquisition equipment integrates a high-resolution CCD camera, a high-magnification microscope, and a precision positioning module, enabling high-definition imaging of micro-traces and repositioned capture to ensure precise acquisition of the same area under varying conditions. A custom algorithm specifically designed for relic micro-trace comparison introduces an innovative adapter-based rapid fusion fine-tuning technique to build customized models for different material types. Blockchain certification technology encrypts and records collected data and comparison results on-chain, establishing a full-process trust mechanism.

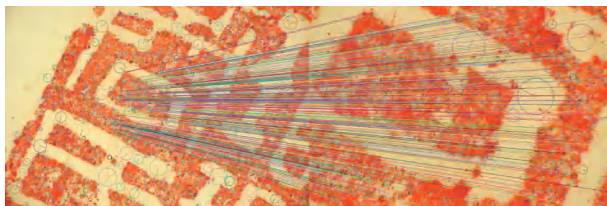


Collection staff comparing cultural relic fingerprint

The project is being implemented in three phases. From January to March 2023, pilot acquisition was conducted on relics of different material types. From April to December 2023, algorithm iteration and platform development were completed. Since December 2023, archival records have been established for over 2,000 cultural relics.

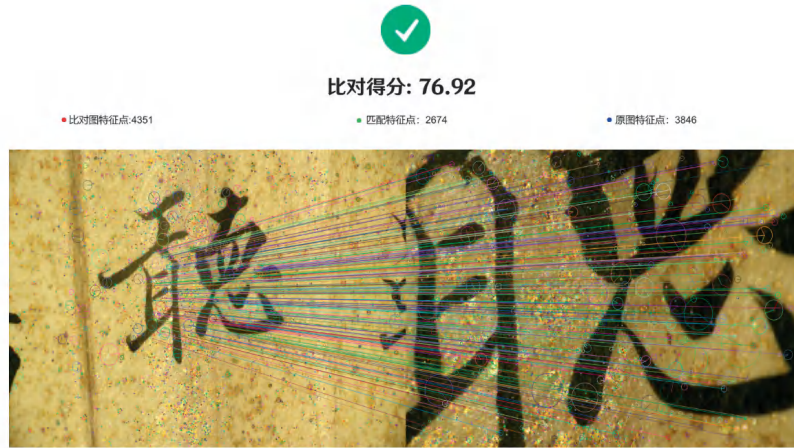
The project has achieved breakthroughs in four dimensions. On the conceptual front, it represents the first systematic effort to use the inherent surface micro-traces of relics for identity authentication. On the technological front, it has developed specialized hardware and AI algorithms, while introducing blockchain to establish a trust mechanism. On the model front, it has pioneered an innovative collaboration model of "small and medium-sized museums + technology companies." On the application front, the outcomes are extendable to auction authentication, forensic appraisal, and other domains.

Practical Outcomes: Digital "Identity Cards" for Over 2,000 Relics



System algorithm matching micro trace feature points

By the end of 2024, the project had completed micro-traces acquisition for over 2,000 cultural relics, generating tens of thousands of feature data points across multiple categories including paintings and



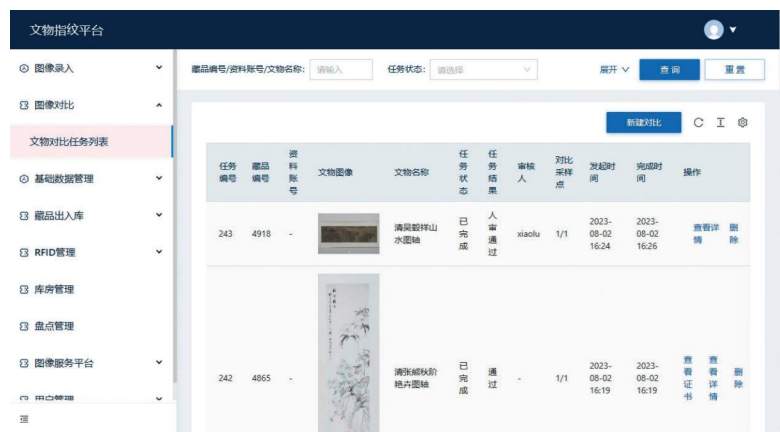
The application compares the real-time image model of the current relic with the original image model stored in the database

calligraphy, jade, ceramics, stone artifacts, gold and silver objects, and bronze wares.

The system has reduced matching time to seconds, with the entire process automatically recorded on-chain, providing robust technical support for clarifying management responsibilities and preventing integrity risks. It has been successfully validated in multiple inter-museum exchanges, successfully completing identity verification during loans and transfers.

Handheld Terminal Development and the Yangtze River Delta Mutual Recognition Platform

In December 2023, the project successfully secured funding under the National Key Research and Development Program. In 2025, development of the third-generation handheld intelligent acquisition terminal was launched, integrating acquisition, matching, and certification functions into a one-handed device, providing convenient tools for field archaeology, relic acquisition, and on-site authentication. By 2026, the project aims to complete acquisition for over 3,000 relics and promote the development of a



Records of cultural relic fingerprint comparison tasks in the application

mutual recognition and data exchange platform across the Yangtze River Delta region. In the longer term, the project aims to extend Chinese-standard relic fingerprint technology to museums along the Belt and Road countries.

Adhering to the principles of demand orientation, technology integration, and standards first, the project provides a quantifiable and replicable solution for the intelligent supervision of cultural relics throughout their circulation lifecycle. Its core transferable lessons include: demand orientation ensures the correct direction of R&D; technology integration creates collaborative synergy; standards first — in parallel with implementation, the project team has initiated the compilation of the Handbook for Relic Micro-Traces Acquisition Procedures to lay the groundwork for standardized dissemination; and market-driven mechanisms provide internal momentum for industry-wide promotion.

Dual Safeguards: Data Security and Algorithm Optimization

On the risk prevention front, the project will continue to expand training datasets to prevent algorithmic misjudgment; clarify data ownership and authorization specifications while promoting the establishment of industry-wide data sharing agreements; and develop lightweight versions while seeking government subsidies to support grassroots deployment.



Cyber Subin: Digital Preservation, Computational Interpretation, and Future Transmission of Southeast Asian Dance Heritage

019

Applicant Institution

Pichet Klunchun Dance Company

This case addresses the digital preservation and transmission of embodied knowledge in traditional dance. Jointly developed by the Pichet Klunchun Dance Company in Thailand and Cyborg Psychology — MIT Media Lab, the project tackles the core challenge that traditional dance — reliant on oral instruction and physical demonstration — is highly vulnerable to loss with the passing of its practitioners. Integrating motion capture, AI-assisted analysis, and embodied data modeling, it has established a multi-layered conservation model encompassing intangible heritage knowledge acquisition, motion capture archiving, computational analysis, AI interpretation, and public presentation, transforming dance into analyzable, teachable, and inheritable digital resources. This offers a replicable paradigm for the preservation of endangered movement-based practices in Southeast Asia and beyond.

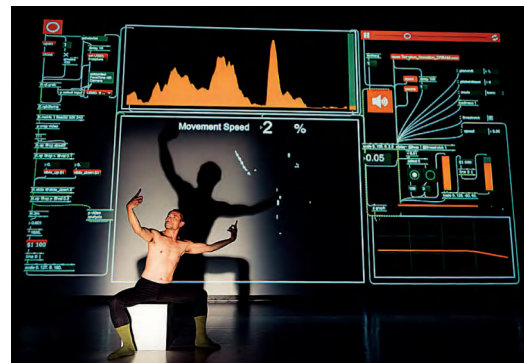
The Fragility of Living Transmission

Dance traditions belong to the realm of embodied knowledge systems, transmitted across generations through memory, repeated practice, and physical movement—inseparable from human carriers and incapable of independent preservation. Their conservation faces three core challenges. First, the ephemerality of intangible heritage: traditional dance relies on living transmission. Once senior practitioners retire or younger generations lose engagement, the movement vocabulary and cultural meanings embedded in the dance face the risk of extinction. Second, the lack of structured documentation for movement systems: existing preservation methods—video recordings, written notation, etc.—can only capture external forms, failing to record spatial positioning of limbs, pathways of force transfer, or choreographic logic, creating a significant gap in heritage preservation. Third, the scarcity of digital systems tailored to embodied heritage: most mainstream digital heritage platforms focus on material artifacts, lacking scalable conservation solutions for living movement practices.

In response, the industry urgently needs a digital pathway that treats dance as a complete language system for preservation, moving beyond surface-level video documentation.

A Five-Layer Conservation Model and Four Core Innovations

The project has established a five-layer comprehensive conservation model. The first layer, intangible heritage knowledge acquisition, works in close collaboration with dance practitioners throughout the process, documenting canonical postures, organizing movement vocabularies, and articulating ritual meanings. The second layer, motion capture archiving, records full three-dimensional movement trajectories of the body, accurately preserving joint coordination, movement rhythms, and spatial structures to create reusable digital archives. The third layer, computational movement analysis, deconstructs movement structures, analyzing body morphology, symmetry, rhythmic patterns, and directional dynamics, transforming dynamic choreography into structured knowledge. The fourth layer, AI-assisted interpretation, employs AI to identify recurring movement patterns, combinations, and choreographic structures, with AI serving as an assistive tool rather than a replacement for performers. The fifth layer, public presentation and interaction, translates the outcomes into digital visualizations, projection performances, and public exhibitions, enabling broader audiences to understand the cultural meanings embedded in the dance.



The five layers progress sequentially — from digital capture of physical movement, to structural analysis, and ultimately to public dissemination of cultural value.

The project's core innovations are reflected in four aspects. First, it moves beyond video recording to preserve the relational logic between movements. Second, it transforms dance into analyzable digital resources, enabling new forms of analysis, teaching, and transmission. Third, it explores human-machine collaborative conservation models, using technology to uncover movement structures and internal patterns that are imperceptible to the naked eye. Fourth, it establishes a replicable methodological framework applicable to various traditional dances and endangered movement-based practices.



A Four-Phase Roadmap and Regional Network Development

Adhering to the principles of deep deconstruction, practitioner-led processes, and open sharing, the project provides a replicable solution for the digital preservation of endangered movement-based practices worldwide. Its core transferable lessons include: deep deconstruction over simple documentation — preserving movement systems and their internal relational logic; human-machine collaboration to uncover movement structures imperceptible to the naked eye; practitioner-led processes throughout to ensure authenticity of cultural expression; and multi-country collaborative networks to promote regional connectivity and open sharing.

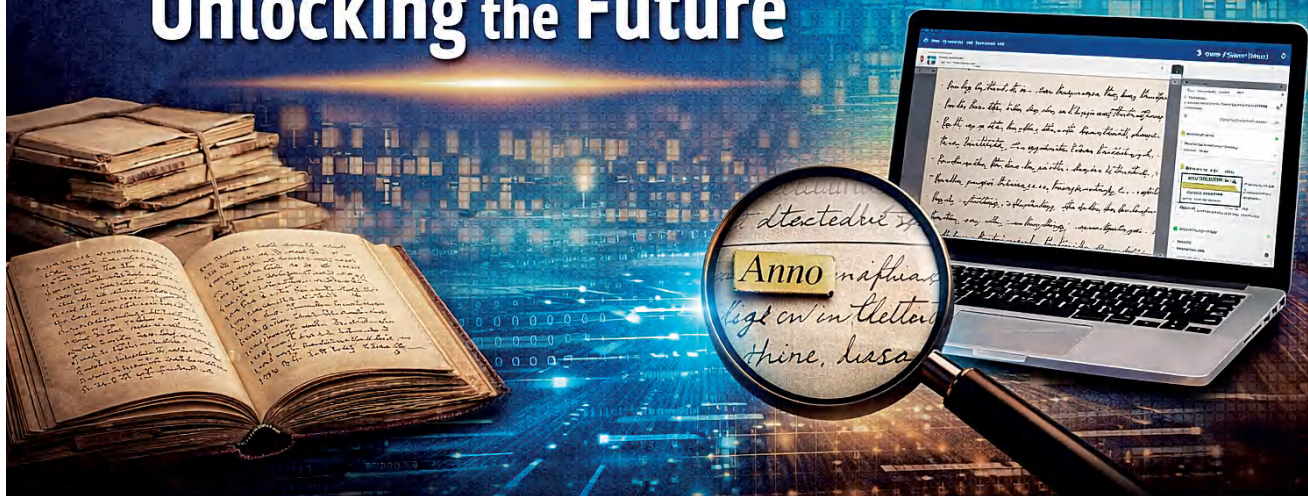
The project is advancing through four phases. In 2026, cross-border collaboration and data collection will be carried out, and a prototype of the conservation system will be developed. From 2026 to 2027,



integration research on AI and robotics will be conducted. In 2027, the premiere of The Tree of Dance and the implementation of pedagogical applications will take place. The long-term goal is to establish a Southeast Asian dance conservation resource repository and a cross-regional movement genealogy map, laying the foundation for systematic preservation of regional dance heritage.

On the risk prevention front, content interpretation will be led by domain experts with practitioners invited to participate in the creative process to prevent oversimplification of cultural meanings; informed consent and compliance protocols will be established to prevent data ownership disputes; and open-standard formats and long-term preservation strategies will be adopted to prevent technological obsolescence.

Digitizing the Past, Unlocking the Future



Handwritten Text Recognition with Transkribus

General Directorate of Archives-Project Transkribus

020

Applicant Institution

General Directorate of Archives

Participating Institution

READ-Coop; Italian State Archives

This case leverages the Transkribus national initiative to build an innovative full-process AI-based handwritten text recognition system tailored for historical handwritten archives, addressing the industry-wide challenges of the inability to perform full-text searches on old handwritten documents and the inefficiency of manual transcription.

Jointly implemented by the READ-COOP European cooperative and the Italian Central Archives Institute, among other institutions, the project promotes the transformation of archives from mere image repositories into intelligent knowledge platforms capable of semantic mining, thereby making cultural heritage accessible to all. This is achieved through the construction of a distributed AI model ecosystem, the implementation of a phased cross-institutional collaborative deployment model, and the establishment of standardized human-machine collaborative workflows.

The Structural Challenges of Intelligent Transcription for Handwritten Archives

Historical archives in many countries have long faced significant challenges in terms of accessibility and large-scale transcription. A vast number of handwritten ancient texts, cadastral records, judicial and notarial documents from the 9th to the 20th centuries feature distinctive scripts and damaged carriers, often legible only to specialists. Manual transcription is costly and time-consuming, resulting in the majority of digitized archives remaining at the stage of "viewing by image" and unable to support full-text search and in-depth utilization.

Furthermore, the heterogeneity of document types — encompassing a wide range of writing styles, layouts, and carriers — renders conventional Optical Character Recognition (OCR) technology largely ineffective for handwritten originals. The necessary supporting infrastructure for the widespread adoption of AI tools — including cross-institutional collaborative workflows, specialized personnel training, high-performance computing and storage, and long-term operations and maintenance — remains in short supply. Additionally, the introduction of AI raises ethical concerns regarding transcription accuracy, algorithmic bias, and potential compromise of the integrity of original historical materials, necessitating the establishment of robust human validation mechanisms and regulatory frameworks.

The Transkribus platform addresses these challenges through an integrated AI framework that supports automated transcription of handwritten archives, domain-specific model reuse, and batch processing of vast volumes of archives, transforming static images into dynamic knowledge resources that are searchable and semantically analyzable.

A Distributed AI Model Ecosystem and a Nationwide Collaborative Implementation System



The project leverages the Transkribus platform as its core infrastructure, integrating deep-learning-based Handwritten Text Recognition (HTR) models, document layout analysis, table baseline detection, and multilingual language models to achieve integrated document zoning, text recognition, and

contextual semantic interpretation.

The platform is modular and customizable. Archives across the country have collaboratively trained over 400 specialized AI models, covering four major categories: text recognition, baseline detection, region segmentation, and table recognition. The system supports batch processing of tens of millions of pages, having processed over 1.7 million pages of archives and completed over 15,000 computing tasks to date.

The project adopts a phased implementation model characterized by "national coordination and distributed deployment," inviting applications from 78 archives nationwide and selecting 30 institutions for pilot implementation. During implementation, capacity building is carried out through targeted training programs and bi-weekly expert seminars. Training data quality is ensured through manual annotation, and large-scale recognition operations are supported by dedicated computing resources. Subsequent institutions are onboarded through the sharing of mature models and practical experience. In the dissemination phase, after manual correction of transcribed content, the results are integrated with digital library systems and made publicly available. In terms of support and infrastructure, the project is equipped with cloud storage and high-performance computing resources, combining public funding with European special project funds. Multidisciplinary teams comprising archivists, AI engineers, and historians have been assembled, and collaborative networks have been established with universities, research institutions, and international cultural organizations.



Five Major Breakthroughs and Multidimensional Value Creation

The project has achieved five major breakthroughs. First, a distributed AI model ecosystem has been established, moving beyond a single generic model to enable each archive to customize its own recognition models adapted to its unique handwritten documents. Second, a nationally coordinated governance system has been developed, facilitating the simultaneous large-scale AI deployment across dozens of archival institutions. Third, a human-machine integrated workflow has been established, with manual annotation and validation ensuring the authenticity of historical materials and AI undertaking batch recognition tasks to enhance processing efficiency. Fourth, archival institutions have been upgraded from mere image repositories to platforms supporting semantic search and knowledge mining. Fifth, a cross-institutional collaboration and sharing mechanism has been established, enabling the wider dissemination of models, solutions, and experiences and reducing redundant R&D investments.

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Risk Mitigation and Long-Term Scaling Roadmap

To address the technical risk of variable recognition accuracy across different document types, the project continues to expand annotated datasets and maintains a regular training and validation cycle. To address the challenge of inconsistent digitization standards across archives, a unified minimum digital quality standard has been issued. On the operational front, computing and storage capacity will be expanded, and regular technical maintenance will be conducted to mitigate system slowdowns caused by high concurrent access. On the organizational front, a phased onboarding approach and regular tiered training will be adopted to address uneven implementation across grassroots institutions. On the ethical front, mandatory manual review will be enforced, and professional archival conservation standards will be strictly observed.

The project is advancing through three phases. Phase I involves completing the transcription and proofreading of existing archived collections and integrating them with digital library systems. Phase II involves onboarding additional archives and building a nationwide shared AI model repository. Phase III involves integrating with European digital cultural infrastructure and participating in the formulation of global archival AI technical standards.

In terms of long-term scaling, the project will continue to advance in three directions: technological iteration, application scenarios, and international cooperation. On the technological front, recognition accuracy will be continuously optimized for complex damaged manuscripts and minority-language handwriting, with entity recognition and knowledge graphs integrated to deepen semantic mining of archives, and interoperability with global digital library systems will be enhanced. On the application front, the scope will expand from national archives to library ancient texts, museum archives, and ecclesiastical and private historical documents. On the international front, the project will actively participate in joint global cultural heritage AI projects, co-build multilingual shared annotation datasets, take the lead in formulating industry standards for archival AI applications, and carry out cross-border technical assistance and capacity-building programs.



海外文物回家

数字文物守护计划

— 百科词条焕新季 —

Baidu Baike Digital Cultural Heritage Guardianship Plan - Bringing Overseas Cultural Relics Home

021

Applicant Institution

Baidu

Participating Institution

CG Model Network

This case focuses on the digitization of tangible cultural heritage, leveraging AI and 3D modeling technologies to build a digital restoration system for overseas-lost cultural relics. It addresses industry-wide challenges such as the inability to conduct on-site scanning of overseas relics, scarcity of reference materials, and limited dissemination, enabling the "virtual return" of lost national treasures through digital means.

Jointly implemented by Baidu and CG Model Network, the project adopts an AI-driven lightweight 3D restoration pathway that does not rely on physical artifacts, achieving high-precision digital reconstruction using only publicly available images. It has established a four-party collaborative mechanism integrating "platform + industry + computing power + think tank," innovated emotional narrative and immersive interaction models, and leveraged International Museum Day to create a full-coverage dissemination matrix, offering a standardized and replicable solution for the digital preservation of lost and damaged cultural relics.



Why Is It Difficult for Lost National Treasures to "Return Home"?

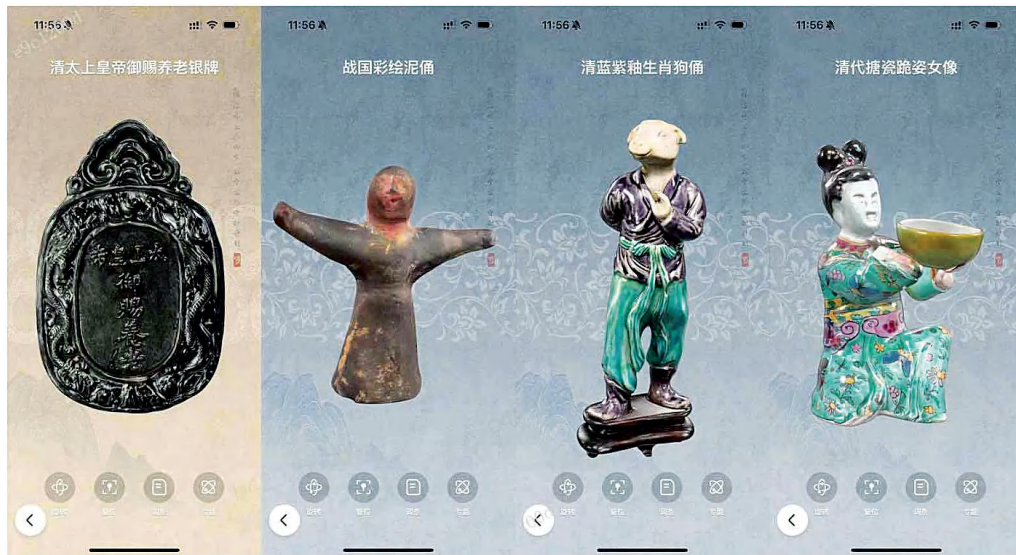
Overseas-lost cultural relics are dispersed across major museums and private collections worldwide, making physical access and high-quality 3D data acquisition extremely challenging. The industry faces multiple shortcomings: high barriers to physical access prevent on-site scanning for modeling data; original digital materials are scarce and of insufficient resolution to support fine-grained modeling; cross-border academic exchange barriers lead to frequent disputes over artifact provenance and authenticity, undermining the scholarly foundation of digital outcomes; traditional image-and-text presentations lack emotional resonance, resulting in limited public awareness of lost relics; and the absence of mature collaborative mechanisms among multiple stakeholders, along with inconsistent standards for copyright and result sharing, constrains large-scale implementation.

In response, the industry urgently needs lightweight digital technologies and multi-stakeholder collaborative models to achieve permanent digital archiving and broad dissemination of lost cultural relics. This project represents a systematic effort to address these challenges.

The AI Reconstruction Pathway: From 2D Images to 3D Models

The project has established a comprehensive technical architecture encompassing "AI-driven generation - 3D modeling - multimodal presentation - immersive interaction - omni-channel dissemination."

On the AI-driven restoration front, Baidu's ACG image-to-3D and AI texture inpainting technologies are employed to reconstruct missing textures and three-dimensional structures from 2D images through deep learning, generating foundational 3D models without the need for physical scanning,



display of the artifact

significantly reducing digitization costs and barriers. On the standardized 3D modeling front, the project collaborates with cultural heritage experts to validate 475 artifact models from four major museums, accurately restoring vessel forms, decorative patterns, and wear traces across multiple categories including bronzes, ceramics, and sculptures. On the multimodal knowledge carrier front, 3D models are embedded into Baidu Baike, creating integrated encyclopedia entries combining "text + images + 3D models" that enable both knowledge retrieval and three-dimensional artifact observation. On the dedicated immersive interaction front, the platform supports 360-degree rotation, zoom, and penetration viewing of interior and base inscriptions, eliminating the sense of distance between viewers and artifacts. On the omni-channel dissemination front, Baidu's ecosystem resources — including splash screens, trending topics, and news feeds — are leveraged in conjunction with external media and KOLs, creating a multi-dimensional dissemination matrix timed to International Museum Day.



The Digital Birth of Overseas Cultural Relics

The project is being implemented in phases. During the preparatory phase, Baidu's platform resources, intelligent cloud computing power, and the CG modeling team were integrated, with a think tank of over 50 cultural heritage experts assembled. A selection of 475 overseas-held Chinese artifacts was made, and documentation and project architecture were completed. During the technical production phase, AI was used to generate 3D artifact models in batches, with expert review and validation throughout. Encyclopedia entries were upgraded, dedicated immersive interaction interfaces were developed, and dynamic presentation videos were produced. The project was officially launched on May 18, 2025, International Museum Day, entering the operational phase. The platform offers free interactive experiences to the public, with continuous optimization of model loading and interaction, alongside full-coverage topic dissemination.



Innovative Practice: From Technological Breakthrough to Emotional Resonance

The project has achieved innovations across multiple dimensions. On the technological front, it represents the first large-scale application of "image-to-3D + AI texture inpainting," breaking through physical scanning limitations and pioneering a lightweight pathway for digital restoration of cultural relics. On the narrative front, it introduces the emotional narrative of "virtual return," integrating digital modeling with cultural and emotional connections to strengthen public resonance. On the collaboration front, it has established a four-in-one collaborative model of "platform traffic + content technology + cloud computing power + cultural heritage think tank," coordinating resources across copyright, scholarship, technology, and dissemination. On the product front, it combines encyclopedia-style knowledge access with dedicated 3D immersive interaction interfaces, serving both academic research and public education needs.

Massive Reach and a Replicable Industry Paradigm

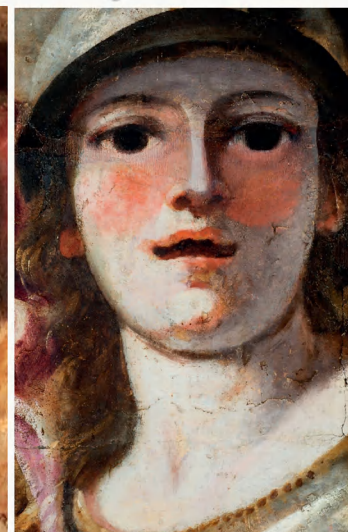
The project has completed high-precision 3D digital archiving of 475 Chinese artifacts held in institutions including the Louvre Museum and the British Museum, reaching tens of millions of users, with digital models remaining accessible online permanently.

The project has delivered value across multiple dimensions. On the conservation front, it has established permanent digital archives for lost cultural relics, mitigating cultural losses from physical damage or loss. On the dissemination front, emotional narratives have expanded beyond niche circles, allowing the public to directly appreciate lost national treasures. On the educational front, 3D interactive resources are suitable for all age groups, providing intuitive and immersive materials for history and aesthetic education. On the industry front, it has created a replicable paradigm for AI-based relic digitization and multi-stakeholder collaboration, drawing industry attention to the digital preservation of lost cultural relics. Future integration with VR/AR will create hybrid viewing experiences, while ongoing iteration of video-to-3D and text-to-3D technologies will further enhance AI modeling precision.

Looking ahead, the project will focus on three key areas. On the educational front, partnerships with primary and secondary schools and universities will develop interdisciplinary curricula integrating history, art, and technology based on 3D artifacts, enabling students to "touch" national treasures in the classroom. On the cultural tourism front, collaborations with museums and cultural venues will establish AR interaction points and VR experience zones to enhance visitor engagement. On the international exchange front, the project will promote "digital artifact" international exhibitions, establish digital resource sharing mechanisms with overseas museums, and foster cross-cultural dialogue. In addition, commercial applications including digital collectibles and cultural and creative product development will be explored, advancing the creative transformation and innovative development of cultural heritage.

Before restoration

After restoration



Analysis of the state of conservation



022

Mattia Preti between Rome and Malta - Diagnostics and Data - Driven Conservation

Applicant Institution

Mantella Giuseppe Restauro S.r.l.

Participating Institution

Rume-Managing Culture

This case builds on the international practice of Giuseppe Mantella Restauri S.r.l. to develop an innovative data-driven conservation system for non-destructive testing of cultural relics, centered on data fidelity, standardized protocols, and practical applicability. It systematically addresses five structural challenges facing the industry.

Moving beyond the prevailing tendency to prioritize equipment accumulation and data collection over practical application, the project employs the 17th-century cross-regional corpus of paintings by Mattia Preti as a testbed. It tackles multiple challenges: incompatible data formats and coordinate standards across various testing methods, preventing effective integration of heterogeneous data; obscure quantitative parameters that are difficult to translate into conservation decisions; prohibitive costs of advanced non-destructive testing that place it beyond the reach of small and medium-sized heritage institutions; ambiguous ownership of digital heritage data that restricts sharing and reuse; and the lack of preservation standards for digital archives, leaving them vulnerable to loss.

In response, the project has established a four-dimensional integrated technical framework encompassing "data acquisition - integration and registration - intelligent interpretation - decision-making and archiving," creating a modular, iterative, and fully closed-loop digital conservation system that transcends traditional experience-based restoration models.



A Standardized Four-Dimensional Integrated Technical Framework

The project has established a four-dimensional integrated technical framework, forming a standardized and iterative closed-loop digital conservation system. At the acquisition layer, equipment calibration standards are unified and non-destructive testing techniques are deployed on demand to ensure the integrity and fidelity of raw data. At the integration layer, file formats and coordinate benchmarks are standardized, and multi-source data — including spectral, 3D, environmental, and archival records — are fused to construct a comprehensive chain of evidence for each artifact. At the interpretation layer, a standardized translation mechanism is established to convert quantitative technical parameters into actionable conservation criteria such as deterioration levels, restoration priorities, and management



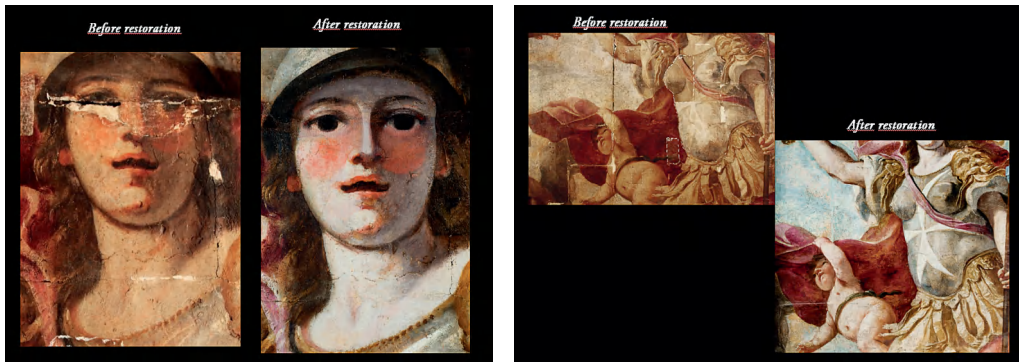
protocols. At the archiving layer, the full chain of evidence — from testing rationale and conservation decisions to restoration interventions — is documented and traceable.

The project follows an eight-stage standardized implementation workflow, encompassing requirements analysis, solution design, on-site acquisition, data fusion, expert interpretation, conservation planning, archiving, and dynamic monitoring, with end-to-end validation conducted on the 17th-century Preti cross-regional painting cycle.

The entire system is built on open-source technologies, making it lightweight, easily replicable, and adaptable to heritage institutions at all levels. Its breakthroughs include: establishing a problem-oriented mechanism that ensures data directly informs conservation decisions; optimizing technical combinations and workflows to significantly reduce the cost of high-end testing, making it accessible across the sector; creating a data translation system that bridges the gap between technical parameters and practical applications; developing standardized operational and training models that reduce dependence on individual expertise; and systematically elucidating the cross-regional material evolution of Preti's paintings, filling an academic gap.

The Scientific Transformation of Data-Driven Conservation and Practical Outcomes

The project has established a triple quality control mechanism encompassing equipment calibration, metadata standards, and historical record verification. All conservation decisions are traceable and



verifiable, ensuring accuracy and reliability from the outset. An innovative iterative archiving model has been developed to address the industry-wide challenge of digital output degradation and loss.

On the social impact front, the project has effectively reduced the costs of testing and conservation for smaller museums and religious institutions, reducing dependence on expensive proprietary technologies and enabling preventive conservation of endangered artifacts. It has also addressed the skills gap in data interpretation among heritage professionals, facilitating the transition from experience-driven to data-driven conservation.

On the academic and industry value front, multi-source data fusion analysis has precisely characterized the materials, techniques, and deterioration patterns of overseas ancient paintings, enriching the international scholarly framework for heritage conservation. The standardized workflows, archiving templates, and training modules are rapidly scalable, enabling grassroots institutions to establish independent conservation capabilities without reliance on external expertise. Drawing on cross-border practice between Italy and China, the project offers a universal paradigm adaptable to diverse national conservation standards, balancing local conservation requirements with technical consistency, and providing a low-cost, highly adaptable international benchmark for non-destructive digital conservation of cultural heritage worldwide.

Technological Iteration and Global Long-Term Deployment

Looking ahead, the project will continue to deepen its focus on data-driven heritage conservation, advancing technological iteration, application expansion, standard refinement, and global deployment to further develop a replicable international benchmark for digital conservation and support the long-term preservation of cultural heritage while advancing open scientific collaboration.

On the technological front, the project will optimize multi-source data fusion algorithms, introduce machine learning to assist deterioration diagnosis, iterate low-cost testing solutions, and refine long-term digital archiving and migration mechanisms to support the development of unified industry standards. On the application front, it will expand to additional artifact categories including ancient paintings, murals, and polychrome sculptures, and extend to scenarios such as museum conservation, university teaching and research, and disaster monitoring. On the international front, it will deepen cross-border collaboration between Europe and China, participate in international standard-setting forums, and establish transnational technical exchange and talent development systems.

甘肃简牍博物馆

简牍文物多光谱采集及病害监测分析项目

Multispectral Acquisition and Disease Monitoring & Analysis Project for Bamboo and Wooden Slips of Gansu Jiandu Museum

案例展示 Case Presentation

彩色影像
Color Image

820nm波段多光谱采集影像
820nm Band Multispectral Image



023

Multispectral Acquisition and Disease Monitoring & Analysis Project for Bamboo and Wooden Slips of Gansu Jiandu Museum

Applicant Institution

Gansu Jiandu Museum

Participating Institution

Tianjin Hengda Cultural Relics Technology Co., Ltd.

This case builds on the collection of over 50,000 Qin and Han dynasty bamboo and wooden slips housed at the Gansu Jiandu Museum, focusing on innovative practices for high-precision digital acquisition and preventive conservation of these bamboo and wooden slips.

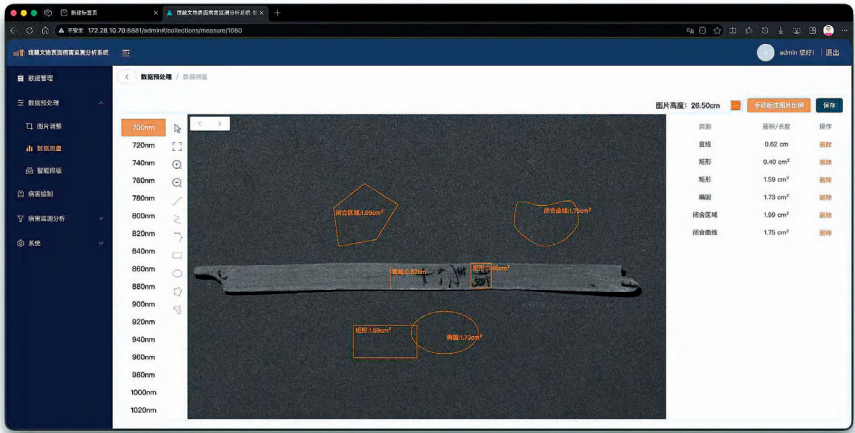
The museum's collection, primarily excavated from ancient sites along the Silk Road, constitutes a core corpus of primary historical materials for the study of Qin-Han history, Silk Road civilization, and Sino-foreign exchange. However, bamboo and wood are inherently fragile materials, commonly affected by ink fading, material aging, micro-damage, and compression marks. A significant proportion of hidden inscriptions and visually imperceptible deterioration cannot be captured through conventional RGB imaging.

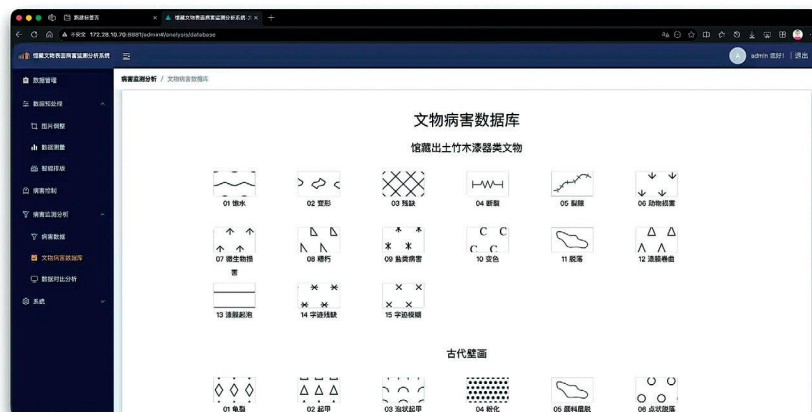
Currently, the industry-standard multispectral equipment features a limited number of channels, making it difficult to capture the subtle spectral differences caused by fading and oxidation on slips, and ineffective at separating ink from bamboo/wood backgrounds. This leads to overlapping critical information, loss of fine details, and insufficient accuracy in digital archives to support precision restoration and in-depth scholarly research. Moreover, deterioration monitoring of slips has long relied on offline documentation, lacking standardized, condition mapping tools. The monitoring process is cumbersome, annotation is inconsistent, and efficiency is low, making it impossible to establish a standardized, traceable long-term conservation mechanism.

Addressing these industry-wide challenges, the project pursues two core breakthroughs: first, enhancing the precision of spectral acquisition and addressing the difficulty of information separation to achieve accurate identification of hidden inscriptions and micro-deterioration; and second, resolving the issues of non-standardized, unclosed, and untraceable deterioration monitoring by establishing a dedicated deterioration database for slips, transitioning conservation from experience-based visual inspection to data-driven precision preventive conservation.

A "Spectral CT" Approach for Bamboo Slips: How 32 Channels Reveal Faded Ink

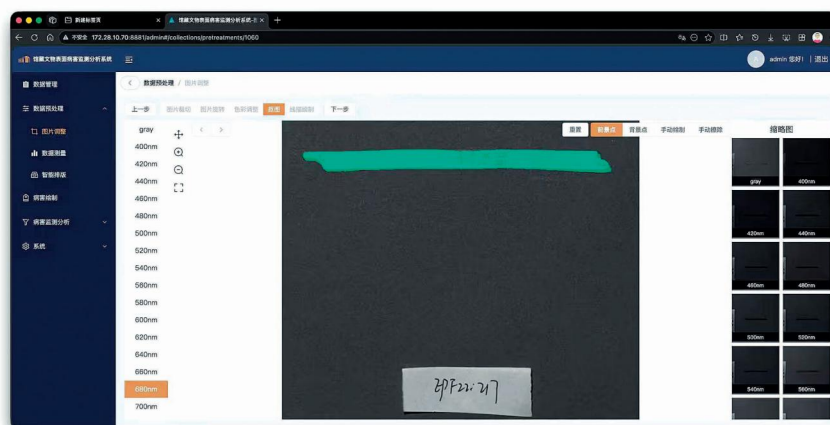
The project has established a three-tier technical architecture encompassing "high-precision acquisition - intelligent spectral analysis - closed-loop deterioration application," using 540 representative slips as a demonstration dataset. Full-spectrum acquisition (400 - 1000 nm) is performed through non-contact, non-destructive methods to ensure artifact safety. By leveraging the differential spectral absorption and reflectance between bamboo/wood substrates and ink, the system achieves integrated spectral and spatial data acquisition. Through multispectral sequence image





fusion analysis, hidden inscriptions are revealed, micro-deterioration is localized, and material aging is identified, generating complete and accurate digital archives for each slip.

The project was implemented in four standardized phases from April to December 2025. During the preparatory phase, acquisition lists were defined, specialized teams were assembled, and system functional requirements were refined. During the core implementation phase, high-precision digital acquisition of all selected slips was completed, a deterioration monitoring and analysis system was established, and computing and storage infrastructure was deployed. During the debugging phase, data accuracy was validated, system performance was optimized, and digital resource management protocols were formalized. Finally, project acceptance and internal standardization were completed, resulting in a replicable operational framework.



Compared with conventional digital conservation approaches, the project has achieved multiple breakthroughs. On the technological front, it pioneered 32-channel narrow-band filtering for fine-grained sampling. With 10 nm bandwidth high-density spectral slicing, subtle spectral differences are captured with precision. At optimized wavelengths, ink and substrate signals are effectively decoupled, fundamentally resolving the challenge of overlapping grayscale values on aged slips. On the application front, a standardized deterioration mapping system compatible with national standards has

been established, featuring a built-in library of standardized deterioration graphic tools, compatible with both 2D color images and multispectral data, substantially improving the efficiency and consistency of deterioration annotation. On the conservation management front, a dedicated deterioration database has been created, enabling multidimensional statistical archiving by deterioration type, size, and distribution, supporting cross-period deterioration comparison, trend analysis, and full-chain traceability, forming a data-driven closed-loop long-term monitoring system.

The project has distilled a replicable methodology characterized by "technology tailored to artifact characteristics, standardized operational protocols, data-driven closed-loop conservation management, and targeted, practical implementation," adaptable to digitization scenarios for bamboo and wooden cultural relics in China.

From 540 Slips to Digital "Avatars": Tangible Outcomes

Since implementation, the project has demonstrated significant results in conservation, cost control, and industry enablement. The standardized acquisition, deterioration monitoring, and closed-loop management system it has developed provides a mature model for the digital conservation of bamboo, wood, and lacquered movable cultural relics in China.



On the conservation front, high-precision digital archiving of all 540 slips has been completed, with artifact information integrity exceeding 98% and hidden deterioration identification accuracy reaching 95%, effectively preventing information loss and irreversible damage. On the cost-benefit front, precision early warning and proactive intervention mechanisms reduce subsequent restoration costs by over 30%, while digital archives significantly reduce the need for physical artifact handling, substantially lowering collection management and operational costs. The project has also driven scenario-based upgrades of smart conservation equipment and digital software. On the social impact front, the high-precision digital archives provide authoritative data for research on Qin-Han history, Silk Road cultures, and Sino-foreign relations. Digital outputs are widely applicable to online exhibitions, educational outreach, and cultural and creative product development, breaking down barriers to collection access, reaching multiple primary and secondary schools, and benefiting tens of thousands of teachers and students.

From Precision Conservation to Full-Collection Coverage: The Pathway Forward

Looking ahead, the project will continue to deepen technological iteration, expand application scenarios, and refine operational systems. On the technological front, deep learning algorithms will be integrated to enhance AI-based deterioration diagnosis models, improving recognition accuracy for micro-damage and hidden deterioration, and enabling intelligent prediction of deterioration trends. On the application front, the digitization of the slip collection will be progressively expanded to cover the entire museum holdings, with applications extended to cultural and creative product development, educational programs, and cultural tourism itineraries, promoting the sustainable use and public engagement of cultural heritage. On the economic and social benefits front, the project will continue to reduce conservation and restoration costs, cultivate new cultural tourism offerings centered on bamboo and wooden slips, and sustain the value of academic research and public education.

At the same time, a comprehensive risk prevention mechanism will be established, encompassing copyright management for cultural and creative products, talent development, and funding and resource safeguards. International technical exchanges in cultural heritage conservation will be actively pursued, disseminating Chinese standards and practical experience in slip digitization, and establishing a leading, replicable benchmark for precision digital conservation of cultural heritage in China.



Asian Ceramics



Online Portal Dutch Collaboration of Asian Ceramics

024

Applicant Institution

Online Portal Dutch Collaboration of Asian Ceramics

Participating Institution

Princessehof National Museum of Ceramics (Lead partner), Rijksmuseum, Kunstmuseum Den Haag, Groninger Museum, Wereldmuseum, Museum Prinsenhof Delft, Jan Menze van Diepen Foundation

This case belongs to the field of museum collection digitization and linked open data applications, focusing on cross-institutional integration and knowledge sharing of dispersed ceramic cultural relics collections.

The project was jointly initiated by the Dutch Collaboration of Asian Ceramics (a coalition of seven institutions). Addressing core pain points such as dispersed data, inconsistent standards, and difficult retrieval of Asian ceramic collections across major Dutch museums, the project builds a search platform based on Wikidata and linked open data technology. It integrates over 20,000 pieces of Chinese and Japanese export porcelain collections. Through data cleaning, content enhancement, and knowledge graph construction, it achieves one-stop discovery and in-depth research across collections, providing a reusable technical paradigm for multi-institutional digital collaboration of cultural heritage.

How to Reunite Scattered Asian Ceramics from Seven Museums

Through the commercial activities of the Dutch East India Company, large quantities of Asian ceramics flowed into Europe, leading major museums to collect vast numbers of Asian ceramic cultural relics. In 2002, four core museums formed a collaborative alliance. The first-generation website launched in 2011 is now technologically outdated and unusable.

The alliance faces three core challenges: First, the seven museums each use different databases and cataloging standards. The same location has multiple name variations (e.g., "Guangzhou" and "Canton" coexist), and Chinese Romanization mixes Pinyin and Wade-Giles, leading to redundant retrieval. Second, multiple museums are gradually replacing their collection databases, with original APIs fully restructured. Some museums are still in the migration phase, making it impossible for the platform to synchronize new data. Third, metadata fields such as place names and dates remain inconsistent and require manual verification, which cannot be fully completed before launch.

Based on this, the industry urgently needs a technical solution that can eliminate format differences and achieve search without modifying each museum's own database. This project was developed precisely for this purpose.

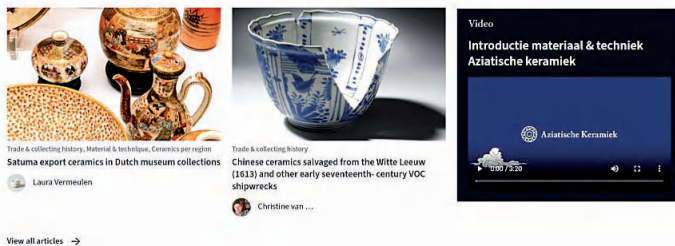
Search Architecture with Wikidata as the Middle Layer

The project uses Wikidata as the middle layer to unify the differentiated data entry formats of each museum without modifying their own databases. The system periodically batch-imports collection data and uses data enhancement scripts for content completion and association matching. When users query, they do not need to access each museum's original database; unified cross-collection retrieval is completed through Wikidata. The platform supports SPARQL querying and CSV export, can efficiently manage complex linked data, adds diverse association descriptions for cultural relics, artisans, and exhibitions, is equipped with an autocomplete operation interface, fully records data modification traces, and supports refined time field entry and multi-format image management.

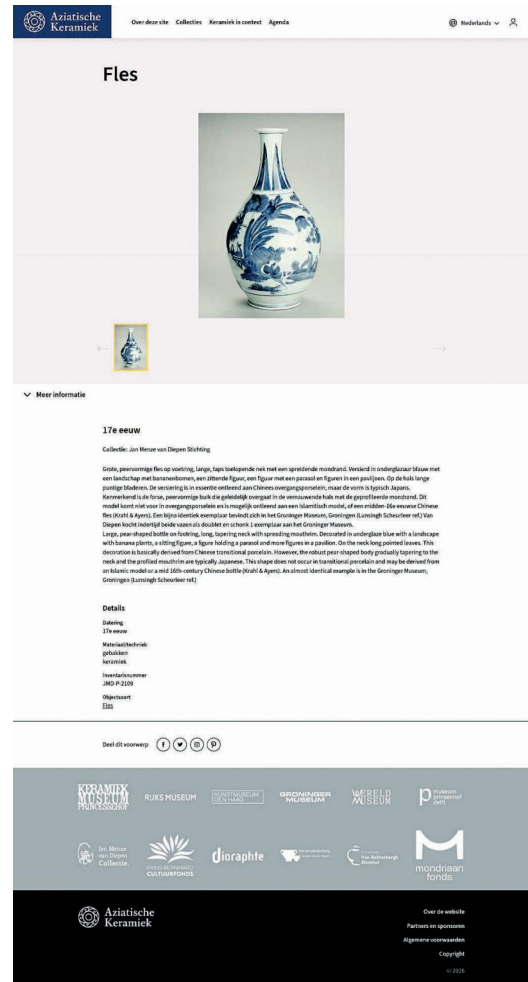
Four core innovations drive industry breakthroughs: search without modifying museum databases, completing data mapping and cleaning through the Wikidata middle layer; Data enhancement and knowledge association, achieving content completion and standardization by connecting authoritative databases through uniform resource identifiers; Multi-version information coexistence allows entry of contradictory historical records and marks preferred source; Sustainable open data ecosystem for global sharing, improving cross-database retrieval interoperability. This middle-layer architecture both respects the data sovereignty of each museum and achieves a search experience across participating collections.



Delve into Asian Ceramic



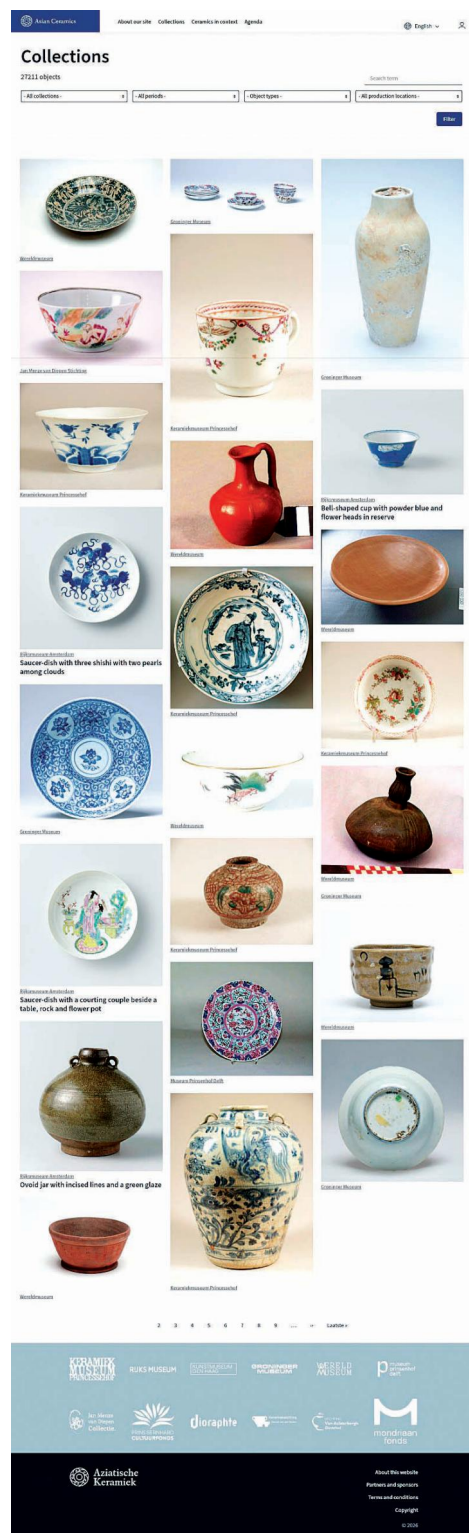
Homepage of the "Asian ceramics from Dutch collections combined" Platform



Collection Search Portal of the Website - Collection Detail Page

From Rapid User Growth to a Comprehensive Thematic Knowledge Base

The new website was launched in April 2023, featuring over 20,000 Asian ceramic objects. In 2025, global visitors reached 25,200, doubling from 2024, with over 4,000 returning users. European visitors accounted for 55% and Asia 36%, with continuously expanding international influence. The platform has added an in-depth thematic article section covering trade history, manufacturing techniques, and collecting history, gradually developing into a professional knowledge base. The platform actively responds to the Dutch national project "Netherlands Collection Highlights" and has become a reference example for the digital opening of museum collections. From user growth to content accumulation, the platform has initially verified the feasibility and sustainability of linked open data in cross-institutional collection integration.



Website Collection Search Portal

Data Cleaning, User Optimization, and International Cooperation Advancing Simultaneously

In 2026, core work will revolve around four main lines: Collaborating with technical partners to standardize chronological information, optimizing origin field classification and connecting to GeoNames geographic coordinates, and manually correcting various spellings and historical transliterations; Launching the sub-project "Asian Ceramics Circulated from Former Dutch Colonies," collaborating with Onsland.nl to sort out the complete circulation trajectory of cultural relics from Asian origins to preservation in Indonesia and finally flowing into the Netherlands, breaking single-perspective interpretation and restoring diverse "life trajectories" for each cultural relic; Analyzing the high bounce rate of Asian users and optimizing interactive experience; Connecting with international resources such as the Dresden Royal Porcelain Project and the Southeast Asian Ceramic Society to promote cross-platform data mutual citation and build a broader knowledge sharing network.

Reusable Paradigm and Risk Prevention

Core replicable experiences of the project include: Linked open data middle layer model, achieving search without modifying each museum's own database; Wikidata collaboration platform supporting multi-institutional, multi-version data collaborative management; Continuous iteration combined with manual verification to establish a long-term data calibration mechanism; Thematic content driving public participation, with in-depth articles enhancing user stickiness and visit volume.

In terms of risk prevention, APIs are gradually connected according to each museum's migration progress, establishing stable data synchronization mechanisms. Manual verification combined with automatic scripts continuously corrects data errors.

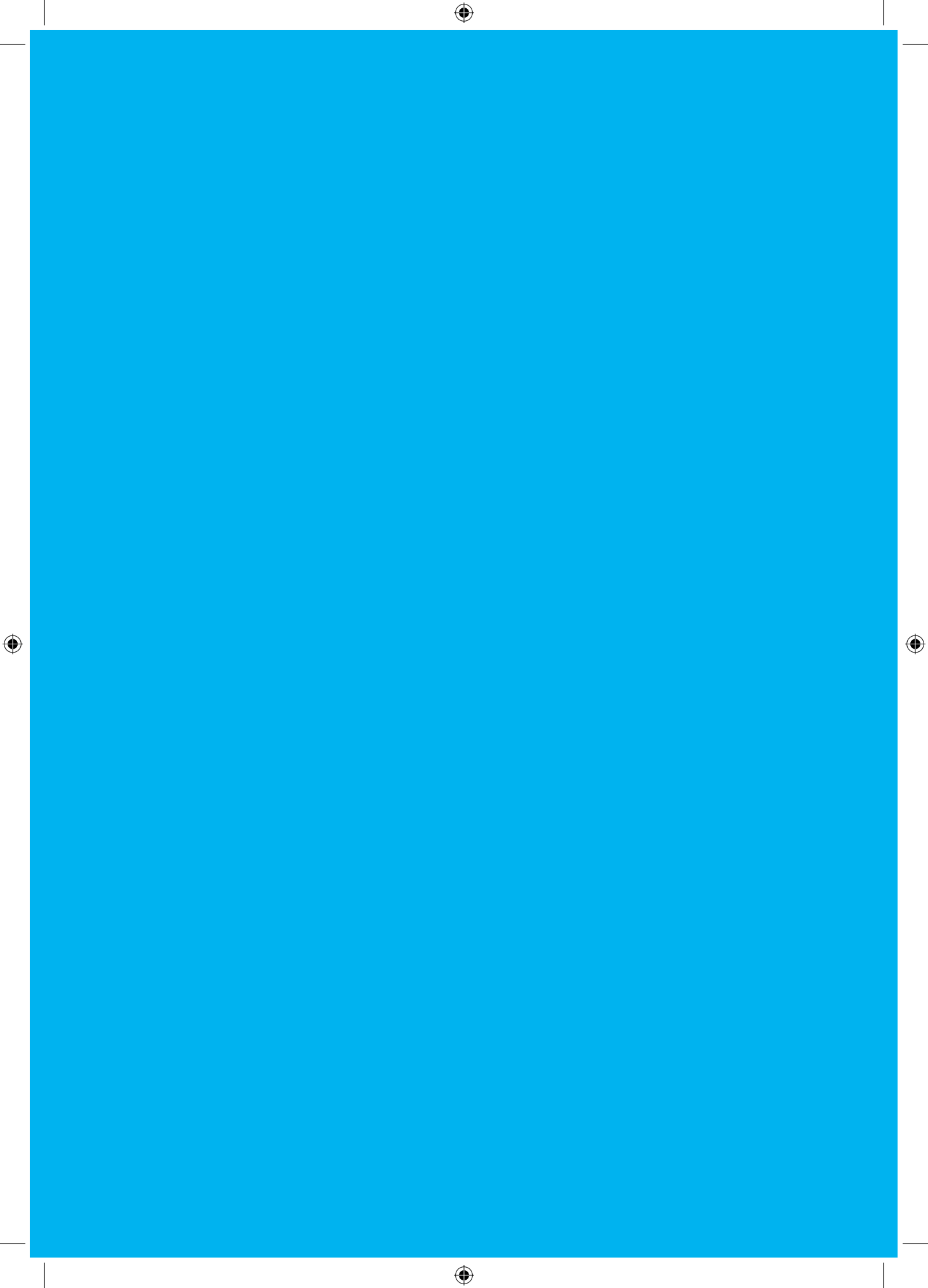


Shunzhi Porcelain – Royer Collection
– Jan van Campen

With limited budgets, priorities are sorted out annually to ensure core functions are implemented first. The project adheres to standards first, open sharing, and gradual optimization, providing reusable solutions for multi-institutional digital collaboration of cultural heritage.

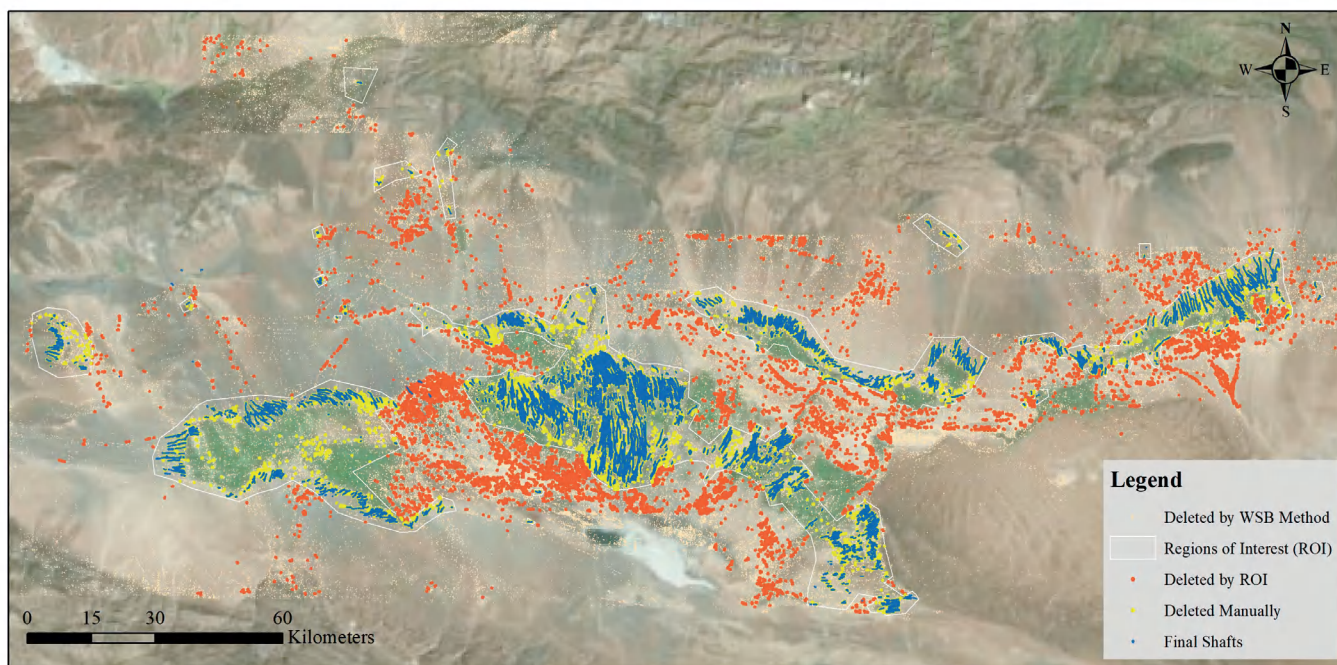
Technological Deepening and the Intangible Cultural Heritage IP Ecosystem Blueprint

Looking ahead, the project will continue to drive technological iteration, IP incubation, and application expansion. On the technology front, efforts will center on enhancing dialect-based AIGC capabilities — including emotional speech synthesis and cross-modal content generation — while releasing offline applications and standardized large-model interfaces to improve digital-human interaction. In terms of content, the project will advance the comprehensive digital archiving of intangible cultural heritage (ICH), develop dialect-enabled ICH virtual personas, establish standardized IP licensing frameworks, and facilitate the integration of digital ICH IP into urban public services. On the industry side, the project will upgrade the AIGC-driven cultural and creative incubation system, build a shared ICH pattern library and co-creation platform, and close the loop from creation and production to sales, while expanding applications in cultural tourism. To ensure quality and trust, a three-tier safeguard mechanism will be put in place — encompassing expert review, privacy protection, and copyright control — ensuring content integrity and data security at every stage. The project will gradually scale its proven model, reinforce its position as a benchmark in culture-tech integration for ICH revitalization, and contribute to the innovative development of China's rich traditional culture.



2

Archaeology



001

Deep Learning and Remote Sensing-Driven Innovation in Karez Heritage Survey: A Case Study of the Turpan Special Survey for the Fourth National Cultural Heritage Census

Applicant Institution

Turpan Bureau of Cultural Relics

Participating Institution

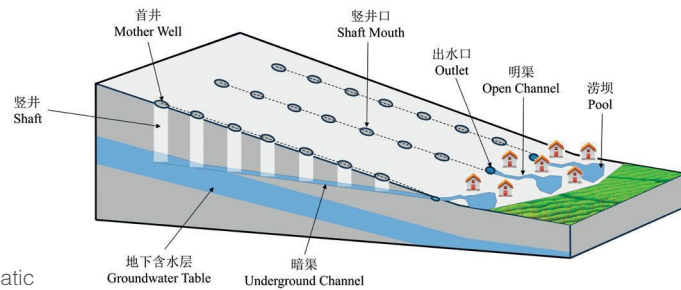
Academy of Turfanology

This case addresses the needs of the Fourth National Cultural Heritage Census, integrating high-resolution remote sensing, deep learning, object detection, and self-developed lightweight mapping application to build an intelligent technical process adapted to the Turpan Karez special survey. It solves the pain points of low efficiency, incomplete coverage, and insufficient mapping standardization in traditional manual on-site surveys, providing a new technical paradigm for digital surveys of linear underground water conservancy cultural heritage.

The project replaces manual visual interpretation with AI remote sensing recognition, achieving automated extraction of massive vertical shafts and greatly reducing field survey costs; It constructs a geospatial screening mechanism to efficiently eliminate model false detections and ensure the accuracy of survey data; It unifies result standards through lightweight mapping tools and establishes a standardized workflow for submitting survey data, providing complete technical support for the investigation, protection, and monitoring of characteristic living heritage in arid areas.

The Three Major Challenges of Manual Field Surveys

Karez is a unique form of ancient underground water-conservancy heritage in Turpan, a national-level key protected cultural heritage site, with local stock accounting for more than 70% of the country, bearing unique historical, technological, and cultural value. Affected by climate warming, declining groundwater levels, and human development disturbances, a large number of Karez vertical shafts have collapsed and corridors have dried up, and the risk of heritage survival continues to intensify.



Typical Karez Schematic

The traditional manual survey model faces three major shortcomings: Karez vertical shafts are densely distributed, with a single project having up to hundreds of vertical shafts, and manual identification one by one is time-consuming and labor-intensive; The Turpan Basin has complex terrain and a wide distribution of heritage, making it difficult to fully cover remote areas; Survey mapping relies on professional GIS software, with high operation thresholds and messy result formats, making standardized data integration and submission difficult.

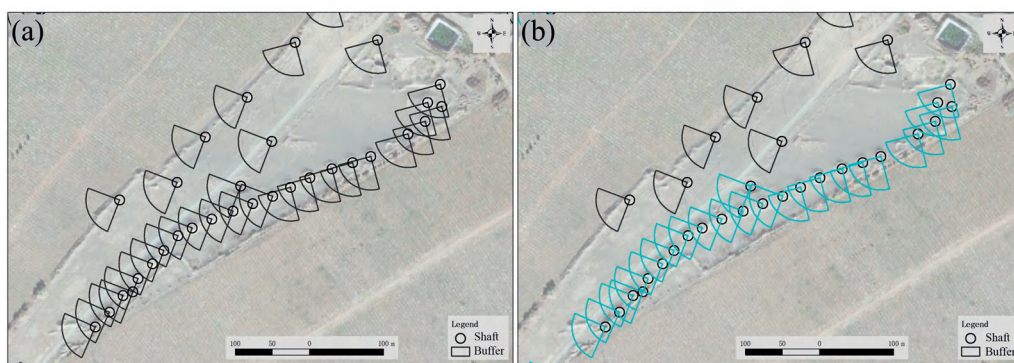
Based on this, there is an urgent need for an efficient, accurate, and easy-to-implement digital survey solution to promote Karez protection from reactive rescue to proactive, science-based conservation with clear baseline data and precise management and control.

From Human Eyes to AI Eyes: How Remote Sensing + Deep Learning Locks Vertical Shafts

The project builds a complete intelligent survey system from three layers: technical path, workflow, and tool development.

Technically, it uses 0.5-meter high-resolution satellite images to cover the entire Turpan Basin, builds a multi-class object detection model based on convolutional neural networks, and selects the MMDetection model with ResNet50 backbone network. The average precision of vertical shaft recognition is 0.833, which can capture subtle surface features compared to manual visual interpretation, and the automatic interpretation efficiency of full-area images is improved by dozens of times.

In terms of workflow, addressing the common problem of false detection in deep learning, the project innovatively proposes a directional fan buffer screening method, relying on terrain slope direction to constrain candidate vertical shaft points, and superimposing hierarchical clustering algorithm to batch filter invalid targets, eliminating 90.20% of false detection data. After multiple rounds of field verification, 88,288 vertical shafts were finally identified, with a total Karez corridor length of 2,527 kilometers, and the overall recognition accuracy of field verification exceeds 99%.



Schematic of Directional Fan-Shaped Buffer Zone Screening Method

In terms of tool development, it independently develops mapping tools adapted to the national cultural relics survey system. Staff can import field vector data to automatically generate standardized floor plans with north arrows, legends, and standard map frames, without professional GIS operation capabilities, unifying the result output format and completely solving the problems of high survey mapping thresholds and non-standard data submission.



Standardized Karez Plan Generation Tool Interface

88,288 Vertical Shafts from Algorithm to Field

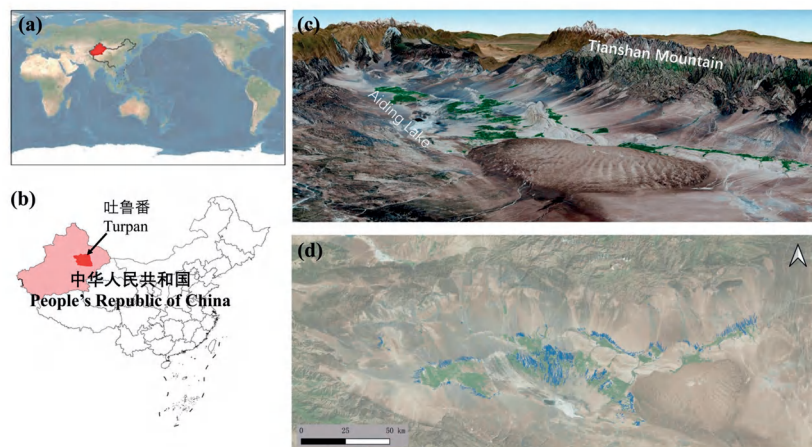
The entire technical system is directly applied to the Turpan Karez special survey. At the survey level, automatic image recognition of the entire area is completed within a few days, and the same workload is shortened by several months compared to traditional manual methods, taking into account full

coverage and ultra-high recognition accuracy. The first set of high-precision Karez spatial database in Turpan has been built, completely retaining the spatial information of vertical shafts and corridors, providing basic data for protection planning, daily management and control, and academic research.

At the industry level, a replicable "remote sensing + AI + GIS" cultural relics survey technology paradigm has been formed, solving the problems of "cannot find, cannot measure accurately, cannot collect uniformly" for special linear heritage, providing a reference for similar characteristic cultural relics surveys nationwide. Academically, related results have been published in authoritative international heritage science journals, gaining global academic recognition; model innovation integrates AI remote sensing interpretation, geospatial correction, and lightweight business tools into an integrated survey pipeline, reducing labor and time costs for large-area remote heritage surveys; technological innovation optimizes the vertical shaft detection algorithm adapted to Gobi landforms through multi-model comparison, and the original terrain constraint screening mechanism greatly reduces AI recognition errors, with supporting customized mini-programs opening up the standardized output link of survey results.

Technology Migration from Turpan to the "Belt and Road"

The versatility and modular design of the project's technical framework enable it to be quickly migrated to other linear heritage survey scenarios, continuously providing technical support for the digital protection of cultural heritage in arid areas, and can be expanded to Karez heritage surveys and protection across Xinjiang and along the "Belt and Road" in Central Asia.



Location Map of the Study Area : (a) Location of China in the World; (b) Location of Turpan in China; (c) 3D Model of Turpan Basin; (d) Distribution Map of Karez in Turpan Basin

In the future, it will integrate multi-spectral, SAR, and LiDAR multi-source remote sensing data to optimize AI models and improve the recognition ability of collapsed and vegetation-obscured vertical shafts; relying on the existing spatial database to access multi-temporal remote sensing and ground sensors, build a long-term change monitoring and risk early warning system for Karez to support management decisions; develop digital display and virtual tour products based on survey data to explore the cultural connotation of Karez and promote public communication and sustainable utilization of living heritage.

遥感考古新范式： LiDAR技术在南方高植被区的系统性实践

申报单位：厦门大学

项目负责人：刘翀



福建省首次遥感考古试点 | 浦城县八担亭止山遗址 | 战国晚期“甲”字形大墓新发现

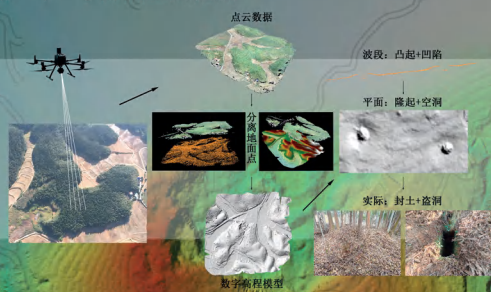
穿透植被·破局之策

以无人机载激光雷达（LiDAR）为核心，攻克林下微地貌获取难题，让隐蔽的遗迹可见可识。

面域全覆盖：打破散点调查局限，提供宏观聚落考古空间数据。

参数最优化：首次确立南方丘陵地带 LiDAR 采集的标准化技术规范。

识别双特征：构建“封土+盗洞”闭环验证体系，大幅降低解译误差。



数字赋能·精准守护

学术贡献：

填补中国南方遥感考古空白，发现率呈数量级跃升，提供可推广的技术参数和评价标准。

保护成效：

为百余座墓葬建立数字化档案，精准发掘M1，出土玉璧、玉剑饰等12件珍贵文物，成功守护珍贵出土文物。

教育普及：

累计培养本硕人才10余名，专业培训基层骨干30余人，成功带动省级文博单位跟进。

产业协同：

验证国产LiDAR装备可靠，促进大型测绘企业深度合作，驱动200km²规模化调查，形成考古遥感数据新业态。

7倍 调查效率提升

60% 调查成本节约

12件 重要文物发现

200km² 呈规模化调查



002

Penetrating the Canopy: Systematic Application of LiDAR Remote Sensing Technology in Tomb Survey of Northern Fujian

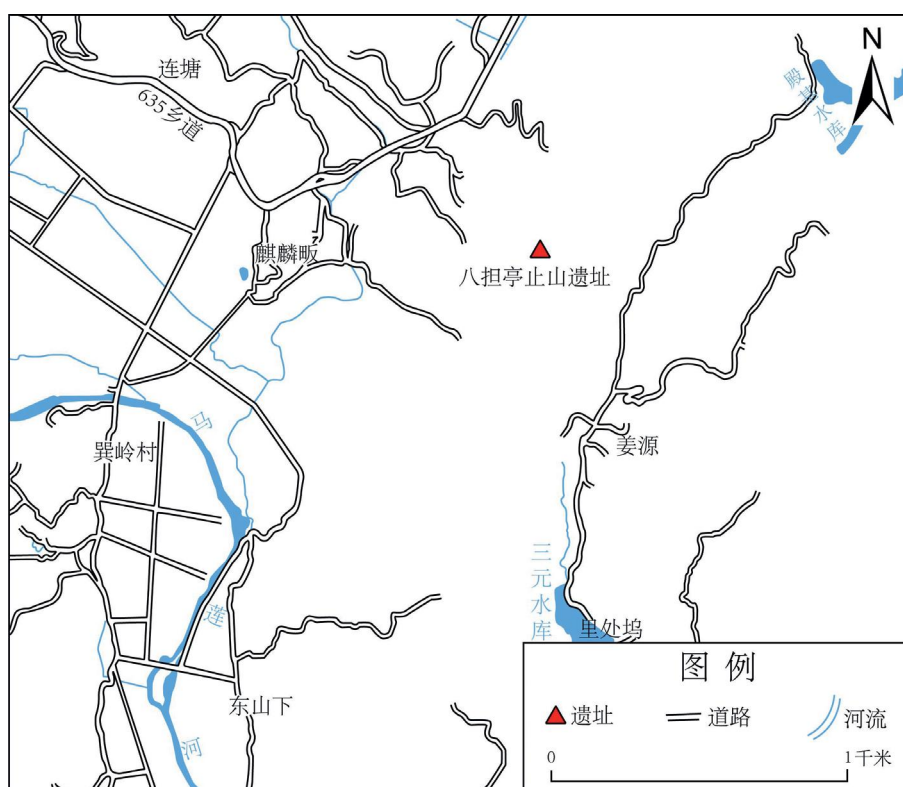
Applicant Institution

Xiamen University

Participating Institution

School of Ethnology and Sociology, Inner Mongolia University; Fujian Institute of Archaeology

This case takes the Badanting Zhishan Site in Pucheng, Fujian, as the experimental area, innovatively using UAV-borne LiDAR technology to systematically solve the industry problems of "invisible, incomplete coverage, impenetrable" in archaeological surveys under high vegetation coverage in southern hills, forming a standardized, cross-region replicable remote sensing archaeology technology paradigm.



Sketch Map Showing the Location of the Site

The project shifts from traditional scattered point surveys to full-area area scanning, increasing the relic discovery rate by an order of magnitude. It clarifies the optimal operation parameters of LiDAR in southern forest areas through controlled experiments; it builds an "air-ground" integrated closed-loop work system and establishes a normalized interdisciplinary collaboration mechanism, providing a complete practical plan for archaeological surveys in similar southern regions.

Archaeological Dilemma Beneath Dense Forests

Hills and mountains are densely forested in southern China, and traditional archaeological surveys face three core bottlenecks. Forest canopies obscure surface micro-topography, making it difficult for manual surveys to identify tomb mounds and robbery pits, and surveying equipment signals are blocked with large collection errors; steep slopes, dense forests, and valleys restrict passage, limiting the coverage of dragnet surveys, and a large number of relics are permanently missed; optical remote sensing can only capture the canopy surface and cannot obtain the real terrain under the forest. Domestic LiDAR archaeology practices in China are mostly implemented in plains and arid areas, lacking parameter systems, data processing workflows, and empirical cases adapted to southern high-vegetation areas; archaeology and surveying disciplines lack stable collaboration mechanisms, and technical solutions are detached from field reality, creating the dilemma of "equipment available but methods difficult to implement".

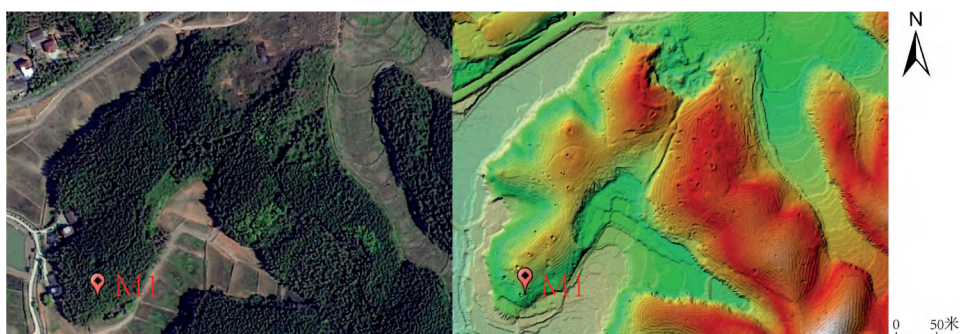
The case carries out research around five core issues: penetrating vegetation to obtain understory

terrain, optimizing flight operation parameters, establishing tomb relic interpretation rules, transforming the full-area survey work model, and building a standardized technical chain and interdisciplinary collaboration mechanism.

LiDAR "Peels Away" Vegetation to See the Surface

The project builds a complete four-layer technical framework of "sensing-processing-interpretation-verification". The sensing layer uses a DJI M300 RTK drone equipped with a Zenmuse L1 LiDAR, relying on three-echo laser penetration of the forest canopy to achieve high-precision point cloud collection; The processing layer completes point cloud registration, coarse and fine ground point classification through professional software, merges multi-flight data for noise reduction, and generates a 1-meter resolution digital elevation model. The interpretation layer relies on DEM to establish a dual-relic identification feature library of "artificially raised mounds + sunken robbery holes". The verification layer is equipped with ground surveys and trial excavations of tombs to verify the accuracy of remote sensing interpretation.

The project is implemented in four phases with a total period of 26 months. The first phase designs 7 groups of controlled experiments to determine winter as the optimal collection window; The second phase completes 7 flight collections; the third phase carries out point cloud processing and relic interpretation; The fourth phase implements full-area ground surveys and rescue trial excavation of the typical tomb M1, unearthing 12 pieces (sets) of precious cultural relics such as jade bi discs and jade sword ornaments. The project first completed pilot verification with 0.2 square kilometers at the Badanting Zhishan Site, identifying more than a hundred suspected tombs, with results far exceeding previous traditional surveys; Then, relying on pilot experience, it carried out large-scale aerial surveys of more than 200 square kilometers in northern Fujian to verify the feasibility of large-scale technology implementation.



Location of Tomb M1

"User Manual" for Southern LiDAR Archaeology

The project summarizes six replicable promotion experiences: The collection window prioritizes winter from December to February of the following year; Parameter configuration follows the principles of low altitude, non-repetitive scanning, and vertical ridge course, clarifying optimal configurations such as 50 to 70 meters flight altitude, vertical ridge course, and 90-degree depression angle. Data processing

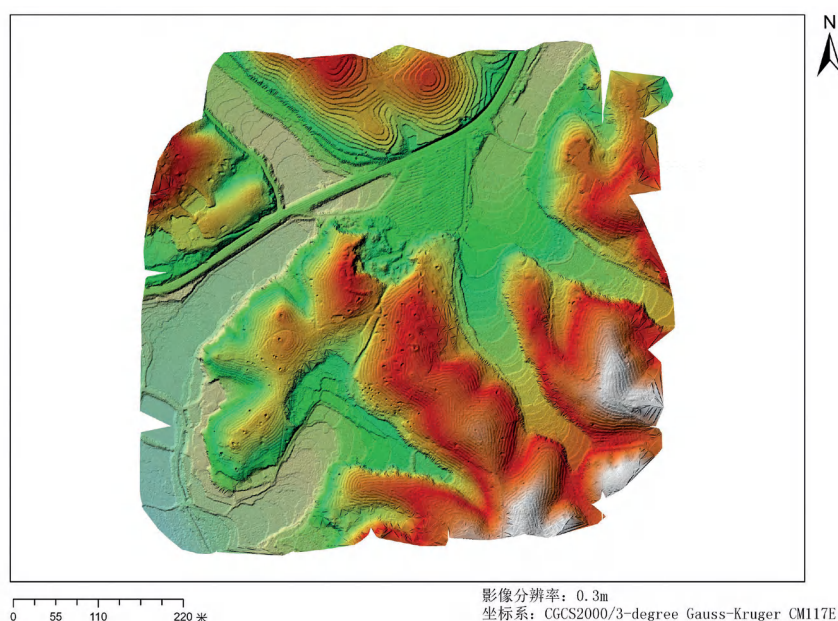
adopts multi-flight merging and hierarchical classification mode; the interpretation stage combines local relic characteristics to build exclusive feature libraries; the verification link establishes a linkage mechanism of remote sensing interpretation, ground survey, and drilling trial excavation; In team building, archaeology and surveying professionals jointly tackle key problems throughout the process, forming a normalized interdisciplinary collaboration team.

The project promotes industry upgrading with three innovative breakthroughs: In terms of model, it achieves a paradigm leap from "scattered point sampling survey" to "full-area census", with a single flight covering a large area without being restricted by ground passage conditions. Technically, through 7 groups of controlled experiments, general standard parameters for southern hills are formed, filling the gap in regional remote sensing archaeology parameters. In terms of process, it establishes multi-flight data complementarity to eliminate detection blind spots, forming a complete closed loop of "remote sensing identification – ground verification – trial excavation evidence", greatly reducing the probability of relic misjudgment.

From Badanting to Northern Fujian: Industry Transformation Driven by Sites

Academically, it fills the gap in systematic airborne LiDAR archaeology in Fujian, produces region-specific technical standards and relic identification rules, and the results are cited by archaeological units in multiple provinces.

In terms of protection, relying on DEM to establish digital archives for understory tombs, accurately locate high-incidence areas of tomb robbery for regular patrols, and carry out rescue trial excavations on severely disturbed tombs, forming a standardized process of "remote sensing first, precise protection".



Digital Elevation Model (DEM) of the Badantingzhi Site (Merged Dataset)

In terms of talent training, LiDAR technology is incorporated into university courses, and special training is carried out for grassroots cultural relics personnel, driving provincial cultural relics units to purchase domestic radar equipment.

At the industrial level, it demonstrates that domestic UAV LiDAR equipment is suitable for complex archaeological scenarios, and collaborates with navigation enterprises to build a large-scale aerial survey service chain, improving the entire industrial chain of archaeological remote sensing data collection, processing, and analysis.

Technology Migration Blueprint from Fujian to Six Southern Provinces

In the future, it will complete LiDAR data analysis of the entire northern Fujian region and build a multi-element identification standard library for tombs, city sites, and mining and metallurgical sites; Integrate multi-source data, such as multispectral and ground-penetrating radar to build a "space-air-ground" detection system. Use time-series remote sensing to establish a dynamic monitoring mechanism for cultural relics safety. Rely on high-density point clouds to complete refined 3D reconstruction of tombs and develop virtual archaeological digital models. Spatially, it will be promoted to the whole province of Fujian and six southern provinces of Jiangxi, Guangdong, Hunan, Guangxi, and Guizhou, and industry technical guidelines will be compiled. The types of relics will be expanded from tombs to city walls, moats, and settlement sites. In terms of culture and tourism, VR virtual archaeology experience products will be developed in collaboration with museums.

In terms of risk guarantee, it will coordinate with meteorological and air traffic control departments to ensure flight windows and reserve project buffer periods, establish a confidence level grading system for relic interpretation to ensure remote sensing clues are verified in the field, strictly implement geographic information confidentiality specifications, and desensitize classified data.



Photographs of Pottery from Tomb M1



Digital Silk Road: Digital Full-Process Collaboration and Heritage Revitalization of the China-Uzbekistan Joint Archaeological Project at Kuva Ancient City

003

Applicant Institution

Archaeology Institute of Luoyang

Participating Institution

Fergana State University, Uzbekistan

Based on the China-Uzbekistan Kuva Ancient City joint archaeological project, this case addresses the needs of "Belt and Road" Silk Road cultural and humanistic exchanges, builds a full-process digital system for transnational archaeology, and solves the pain points of inconsistent standards for transnational archaeology of earthen sites in Central Asia, difficulties in long-distance collaboration, and insufficient heritage activation.

The project establishes unified digital operation standards to eliminate data barriers between Chinese and foreign teams. Builds a "field-cloud" collaborative architecture to break the time and space constraints of transnational collaboration; realizes multi-scenario transformation of archaeological digital assets, simultaneously supporting cultural relic protection, academic research, talent cultivation, and international communication, providing a standardized and promotable paradigm for Silk Road cross-border archaeology.

Triple Dilemma of Standards, Collaboration, and Activation

Earthen sites in Central Asia are important carriers of Silk Road civilization exchanges, but archaeological protection faces three prominent problems. Archaeological records are fragmented and standards are inconsistent. Traditional manual surveying and mapping data have uneven precision, and the operation specifications of China and Uzbekistan differ greatly, making it difficult to form a unified spatial database, which is not conducive to long-term monitoring and multidisciplinary research. Transnational collaboration has obvious time and space constraints. Remote teams cannot share excavation information in real time, and rear experts have difficulty in remotely judging relics; Earthen sites quickly weather and are damaged after being exposed, and it is difficult to completely retain and review excavation data at each stage. There are shortcomings in the protection and display of earthen sites. Mud brick and rammed earth remains are fragile and easily damaged, and traditional display forms are difficult to convey historical value to the public, and the educational and communication value of heritage cannot be fully released.

The case focuses on three core issues: unifying China-Uzbekistan digital collection and archiving standards, building an efficient transnational collaboration mechanism relying on digital technology, and transforming archaeological data into sustainable digital assets to empower protection, scientific research, cultural tourism, and international exchanges.



Archaeological Excavation of Kuva Ancient City



Field Archaeological Survey
of Kuva Ancient City

Three-Layer Technical Architecture from Field to Cloud

The project builds an integrated digital archaeology technical framework, covering the entire chain of excavation, processing, and application. The field collection layer uses RTK surveying and mapping drones and SLR cameras, combined with refined excavation methods, to carry out measurable and traceable digital collection of strata, relics, and artifacts. The cloud processing layer generates orthophotos and 3D models with the help of photogrammetry and GIS software and relies on cloud platforms to achieve transnational data sharing and expert remote consultation. The application activation layer serves four scenarios: academic paper publication, offline science popularization display, immersive teaching materials, and site park planning.

The project is implemented in three phases throughout the cycle: The first phase unifies the site reference coordinate system and excavation grid layout standards, collects full-area landforms and key relic images through air-ground coordination, and digitally analyzes exploration borehole data to accurately restore the distribution of underground rammed earth remains. The second phase uses high-precision digital images as the unified judgement base for both parties, clarifies the three-phase construction context of the city wall through profile digital records, and carries out remote joint research on artifacts by Chinese and foreign experts relying on online 3D models and images, avoiding personnel cross-border and physical transportation restrictions. The third phase supports academic journal publication with digital achievements, produces "Silk Road Searching for Qian" cultural and creative products and campus digital achievement corridors, and provides core basis for local site protection planning and archaeological park construction with full-area high-precision terrain data.

Triple Breakthroughs in Technology, Collaboration, and Value

In the early stage of the project, unify coordinate, collection, and archiving standards to achieve standardization first. Select portable and compliant equipment to adapt to overseas operation conditions and achieve lightweight deployment; Incorporate digital collection into daily excavation processes to achieve process embedding; balance scientific research protection with talent training

and public communication to achieve two-way empowerment and form a virtuous cycle.

In terms of technology integration, adapting to fragile rammed earth and mud brick sites in Central Asia, integrating drones, RTK, and 3D reconstruction technology to form a lightweight, low-cost standardized digital recording solution; In terms of collaboration mode, upgrading from traditional separate recording and later summarization to unified digital base real-time collaboration, with digital achievements becoming the core carrier of the entire process of transnational archaeological collaboration; in terms of value extension, opening up the link between field data and youth exchanges and cultural and creative creation, promoting the creative transformation of archaeological achievements and maximizing the social value of cultural heritage.

Dual Value of Permanent Archives and Silk Road Cultural Creativity

In terms of protection effectiveness, the project has completed digital archiving of the entire area of the north city gate and palace exploration area, retaining a permanent digital twin archive of the site, identifying multi-layer construction techniques of the city wall through image analysis, and discovering 690 square meters of underground rammed earth foundation sites, filling the gap in the study of the ancient city layout.

In terms of communication effectiveness, multilingual Chinese and foreign media have widely reported the cooperation results, multiple archaeological papers have been published to enhance regional academic influence, youth cultural activities and the "Silk Road Searching for Qian" cultural and creative project have won first prizes in national competitions, and the international communication effect is outstanding.

In terms of education and industrial effectiveness, regular digital archaeology training for Uzbek personnel is carried out to achieve local technology output, joint archaeological bases and cultural



Unveiling of the Archaeological Base and Laboratory Cooperation Platform

relics restoration laboratories are established, and a complete value chain of "excavation - research - cultural creativity" is constructed.

Future Blueprint from Kuva Ancient City to the Silk Road

In the future, it will complete 110,000 square meters of the ancient city's full-area 3D digital twin modeling, integrate multi-source detection data such as carbon-14 and DNA to build a comprehensive GIS platform, and explore AI automatic identification and classification of pottery shards. Develop VR/AR virtual site systems for teaching in both places, rely on 3D models to support site park planning, and continuously expand cooperation with global universities and institutions.

In terms of risk guarantee, apply for special funds through multiple channels and cultivate a China-



Cultural Exchange Activity: "Belt and Road, Childlike Innocence"

Uzbekistan joint digital archaeology team, establish multiple data backups and national-level platform archiving mechanisms, clarify intellectual property rights of digital assets in cooperation agreements, and prioritize portable and compliant equipment overseas and adopt offline collection and regular return mode.



004

Bridging Institutions and Innovation: A Digital Heritage Management Model for Italy's Archaeological Landscape

Applicant Institution

RUME – Managing Culture

Participating Institution

Keiron Interactive JDK, Methodo, Katatexilus, Visivalab

This case innovatively constructs a comprehensive digital heritage governance system of "four-layer technical architecture + five-stage implementation process". Relying on the RUME hybrid intermediary institution, it breaks through public-private, cross-regional, and transnational heritage management barriers, effectively solving the pain points of scattered digital governance of Italian cultural heritage, uneven resources, and disconnected technology implementation.

The project innovates the public-private cross-border coordination model to solve the problems of fragmented rights and responsibilities of multiple subjects and lack of compound talents. Builds a standardized layered digital technology base, covering all scenarios of digital protection of cultural relics, immersive public experience, intelligent guidance, and transnational resource sharing; Creates a replicable implementation process and diversified funding guarantee system, providing a high-quality model for digital construction of cultural heritage under the global decentralized governance model.

Digital Dilemma Under Decentralized Governance

Italy has rich archaeological and cultural heritage resources, but digital construction lags behind, with a significant gap between supply and demand, facing challenges from multiple aspects: First, local heritage governance rights and responsibilities are scattered among multi-level institutions, and the core bottleneck of digital transformation is actually organizational management rather than technical issues. Second, institutional barriers are prominent, digital standards are messy, and compound professional talents are scarce, seriously restricting digital implementation. Third, although Italy's National Recovery and Resilience Plan (PNRR) has injected a large amount of funds into the industry, due to the lack of coordination mechanisms, projects are scattered and system interoperability is poor, easily forming a fragmented construction situation. Fourth, a large number of museum collections have been sealed for a long time without activation, and underwater and remote sites cannot be opened to the public due to conditions; Fifth, traditional guidance at popular sites is difficult to adapt to diverse digital tour needs, cross-institutional cooperation is cumbersome and inefficient, small and medium-sized cities lack resources for digital heritage construction, and the regional digital divide is significant. The five core problems are intertwined, and there is an urgent need for a systematic solution that can coordinate multiple resources and break through governance barriers.

Four-Layer Technical Architecture and Five-Stage Implementation Process

The project builds a four-layer, full-chain standardized digital technology system, empowering heritage protection and activation in all aspects. The bottom layer is the digital cataloging infrastructure. Through high-precision 3D scanning and unified metadata standards, it completes batch digitization of museum collections in six regions of southern Italy. The results are compatible with mainstream heritage platforms, ensuring the scientific research value and public accessibility of digital resources. The second layer is immersive experience technology. Relying on the Baia Underwater Ancient City VR project, the site is scientifically restored based on field survey data, solving the problem of opening inaccessible sites. The third layer is the AI intelligent interpretation system, creating multilingual interactive AI guides that can adapt to different tourist needs and link real-time scene data. It has been implemented at multiple sites and has strong reusability. The top layer is the transnational digital sharing platform, jointly building the Adriatic Virtual Museum with multiple countries to achieve cross-border heritage resource sharing, joint exhibitions, and collaborative scientific research.

The case is equipped with a standardized five-stage implementation process, including sorting out institutional rights and responsibilities and building a cooperation system, linking academia to formulate scientific and technological standards, coordinating technical teams to complete development and integration, implementing deployment and carrying out operation and maintenance training, archiving

results and refining methods for promotion and replication. The entire process is standardized, implementable, and reusable.

The project implements a phased gradient promotion model: Phase I integration period is 2025 to 2026, implementing core digital projects and compiling standardized methodologies; Phase II expansion period is 2026 to 2027, replicating the AI guide model and establishing a permanent governance mechanism for transnational platforms; Phase III international scale period is 2027 to 2029, building a multi-country linked Mediterranean digital heritage network and participating in formulating international digital heritage standards. Simultaneously, relying on the World Internet Conference to build an "Italian Heritage" exhibition space, creating a national-level demonstration window for international exchange in digital heritage.

Dual Innovation of Governance Model and Technology

At the model level, the project relies on the RUME institution to build a public-private cross-border coordination carrier, coordinating multiple subjects such as government, enterprises, and academic institutions with a lightweight team, innovating a transnational heritage collaborative governance mechanism, breaking the institutional limitations of national boundaries and rights and responsibilities division, and effectively solving the problems of long-standing institutional barriers and scattered resources in Italian heritage governance.

Technically, the project adheres to the bottom line of academic rigor, adopts a modular and iterative architecture, unifies digital resource standards, and builds an integrated technical system of 3D digitization, AI, and digital twins adapted to multiple scenarios, effectively avoiding problems such as technological iteration obsolescence and system incompatibility.

Relying on this, the project revitalizes a large number of sealed cultural relic digital resources, providing new support for international archaeological research, and achieving permanent digital preservation of remote and underwater sites. Immersive digital experience can improve tourist experience by 30% to 40%, while standardized construction reduces repeated investment, deriving new digital cultural tourism formats. Inclusive digital resources break heritage access barriers and narrow the regional digital divide. Cross-domain cooperation barriers are broken, and a sustainable operation system of public-



Immersive Visitor Experience

private collaboration and multi-country linkage is constructed, providing a benchmark of digital governance of national heritage for similar countries.

From Italy to the Mediterranean: Future Expansion Blueprint

In the future, it will continue to upgrade from three aspects: technology, scenarios, and guarantees. Technically, iterate AI recognition and wearable AR technology, develop dynamic digital twins of sites, and improve unified standards for transnational platforms. In terms of scenarios, the achievement will be expanded to the field of global world heritage and post-disaster heritage restoration, with the Mediterranean multi-country digital heritage network to be implemented. In terms of guarantees, build diversified financing channels, adopt a lightweight elastic team model, and establish five risk prevention and control mechanisms: institutional changes, technological obsolescence, funding fluctuations, digital divide, and intellectual property rights, to ensure long-term stable and sustainable development of the project.



Exchange Activity

广州市文物考古“一张图”资源数据库项目



005

Guangzhou Municipal Cultural Relics and Archaeology "One Map" Resource Database Project

Applicant Institution

Guangzhou Municipal Institute of Cultural Heritage and Archaeology (Cultural Heritage Preservation, Management and Research Center of Maritime Silk Road (Guangzhou), Southern Han Mausoleums Museum)

Participating Institution

Xi'an YunTu Information Technology Co., Ltd.

This case focuses on the digital and spatial governance of cultural relic archaeological archives under the background of large-scale urban infrastructure construction with pre-archaeology. The project is led and implemented by the Guangzhou Institute of Cultural Relics and Archaeology. Addressing the core pain points, such as isolated and fragmented massive supporting paper archives accumulated over a decade and lack of unified spatial benchmarks, which easily lead to repeated archaeology and financial waste, it builds a five-layer technical system and forms a set of standardized and reusable digital governance methodology for mega-city archaeology with the construction concept of "unified base, data-driven, business integration".

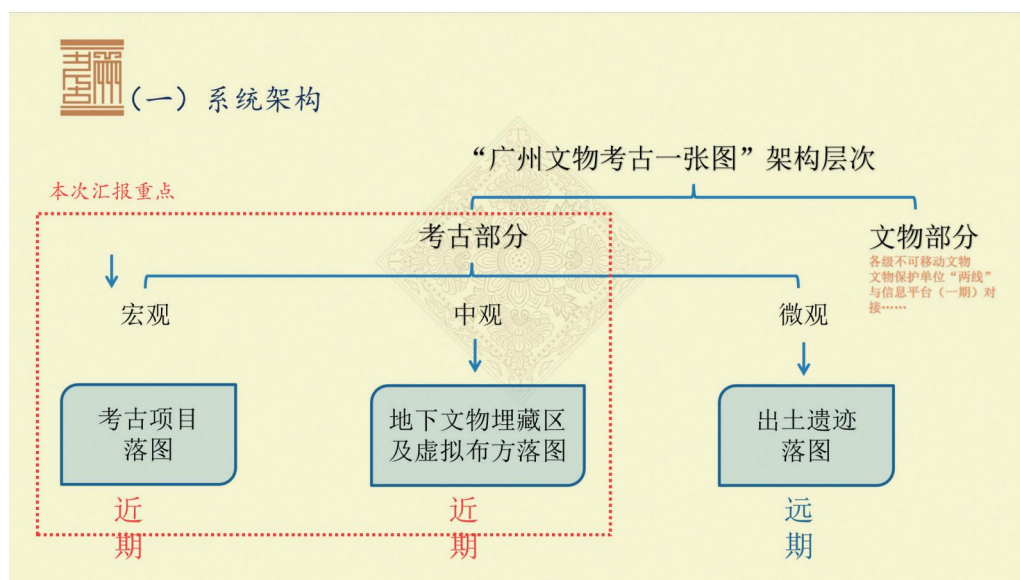
The Dilemma of "Archive Backlog" Under the Pre-Archaeology Reform

Since Guangzhou implemented the pre-archaeology reform more than ten years ago, it has carried out more than 3,300 infrastructure archaeology projects in total, accumulating massive paper archives and hand-drawn drawings. It now faces four core management problems: lack of a unified geographic coordinate system, disappearance of reference objects or missing of coordinates for historical archives, which lead to repeated archaeology on the same plot, causing financial waste and audit risks; paper drawings are stored in a scattered manner, difficult to retrieve, reflecting lagging-behind in digital and structured processing ability; various business systems are independent of each other, so that exploration, excavation, and archive management data cannot be interconnectedly shared; lack of unified collection, storage, and management standards, restricting long-term data availability and cross-departmental collaboration.

Therefore, the industry urgently needs a digital governance solution based on a unified spatial base and covering the entire archaeological chain.

Five-Layer Technical System Allows Underground Relics to "Accurately Fall on the Map"

The project adopts an integrated technical architecture of "cloud-data-intelligence-application" to build a five-layer technical system based on the "Guangzhou 2000 Coordinate System" as the unified geographic benchmark. The data layer integrates multi-source heterogeneous data such as basic geographic information, historical maps, archaeological exploration and excavation data. The platform layer provides spatiotemporal data services and GIS spatial analysis services, following standard interfaces to ensure data interoperability. The application layer develops archaeological excavation digital systems, one-map comprehensive application systems, spatiotemporal model analysis systems, etc., fully covering the archaeological business chain. The display layer builds a big data



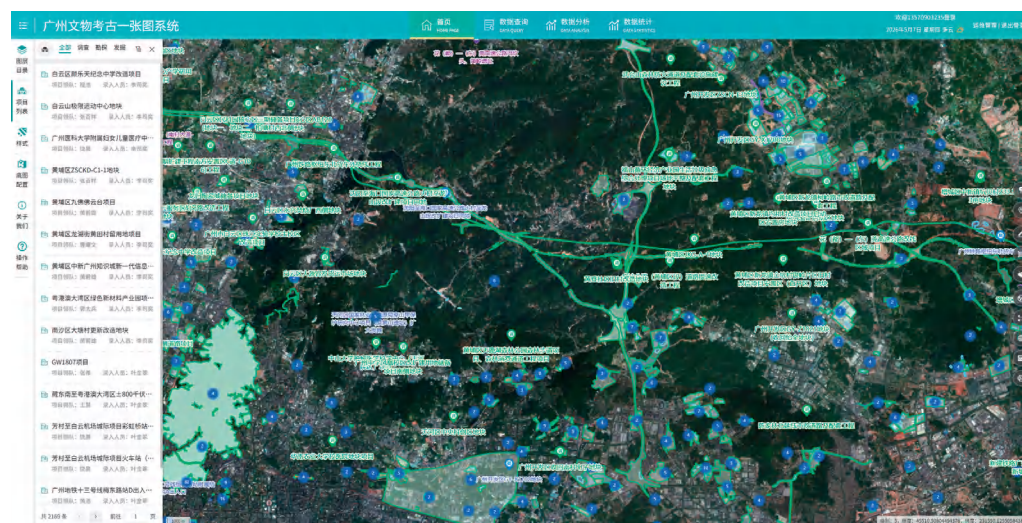
System Architecture

cockpit for cultural relics archaeology, realizing integrated visualization of resource distribution and safety monitoring; The operation and maintenance layer builds a user authority and log audit system to ensure system security and stability.

In terms of core technology, the project overcomes the problem of spatial registration of old data. Through multi-feature point fitting of raster images and high-definition satellite images, the positioning error is controlled within 1 to 3 meters. It pioneered the "Guangzhou Archaeological Project Metadata Specification" to unify the underlying data language, created the "virtual grid positioning method", setting up 500-meter macro grids and 10-meter micro-excavation grids centered on the city origin, achieving absolutely precise positioning of underground non-visible relics, and deeply connecting with territorial spatial planning.

The project implementation follows the principle of "business-oriented, phased iteration". Phase I completed accurate mapping of 1,359 archaeological archives from 2017 to 2021. Phase II broke through data barriers of various business systems to build an integrated data resource center. Phase III built a decision-making platform and big data cockpit.

The four innovative breakthroughs of the project include: Unified base first, building geographic base maps with urban unified spatial coordinates; Pioneering metadata specifications and a virtual grid positioning method to provide precise positioning for underground relics; Building a five-layer technical system to form a complete closed loop; Deep integration of business and technology, strictly following archaeological procedures to ensure system construction fits reality.



Project Data Mapping

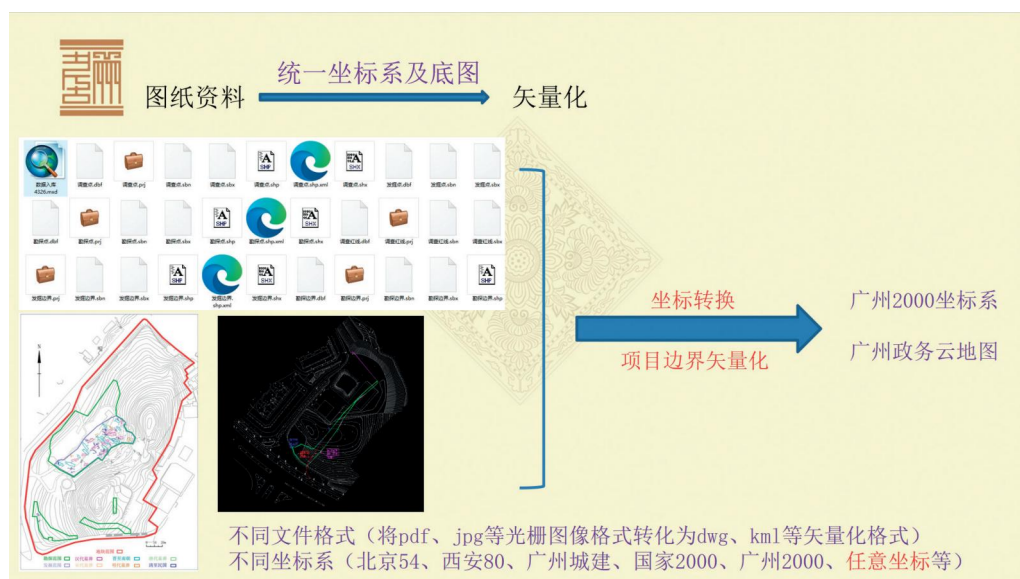
Efficiency Revolution Behind 1,359 Archaeological Archives

Phase I of the project completed accurate mapping of 1,359 archaeological archives, with the survey project area coverage rate exceeding 96% and total data assets of 360.57GB. Managers can conduct multi-dimensional spatial queries and avoidance analysis through the "data cockpit", eliminating repeated exploration and improving management efficiency by more than 5 times. Digital archives provide intuitive spatial information support for academic research, helping to explore the internal

relationship between human activity patterns and the geographical environment. The project ensures the permanent preservation and inheritance of Guangzhou's archaeological materials, providing a "Guangzhou Plan" for megacities to address unclear historical and archaeological records.

Advanced Path from Passive Recording to Active Empowerment

The project adheres to a unified base, standards first, and business integration, providing replicable solutions for digital governance of mega-city archaeology. Core replicable experiences include: taking a unified base first as the primary prerequisite for digital implementation of cultural relics; Standard specification leading, formulating standards first and then carrying out large-scale construction; Phased iteration implementation reduces implementation risks; Deep integration of business and technology ensures the system is easy to use.



Vectorization Process

In the next 1 to 2 years, introduce a hot and cold data separation storage mechanism and explore AI-assisted automatic identification and extraction of archive text; In 2 to 3 years, promote the leap from "passive recording" to "active empowerment", achieve full coverage of cultural heritage resources in the spatiotemporal dimension, and simultaneously implement A/B/C three-level differentiated fine management and control.

In terms of risk prevention and control, a dual verification closed loop of "system initial calculation + manual field re-survey" will be established, and confidence labels will be assigned to data of different precisions. Physical isolation of internal and external networks will be strictly implemented and data desensitization will be adopted on the public end. Historical data authorization compliance will be verified, and open API interfaces will be reserved to ensure smooth system upgrades.

3

Exhibition and Utilization



001

The Palace Museum Digital Twin Application for Large Comprehensive Museums

Applicant Institution

The Palace Museum

Participating Institution

Tianjin University; Wuhan University; Beihang University; Beijing University of Posts and Telecommunications; Beijing University of Civil Engineering and Architecture; Beijing SuperMap Software Co., Ltd.; Beijing Amap Cloud Map Technology Co., Ltd; China Unicom Digital Technology Co., Ltd

This case faces the integrated cultural museum scenario of "museum-ancient building complex -tourist attraction", and builds a new digital public service system with digital twins as the core. It carries out full-chain research on theory, technology, and platform around heritage protection, public experience, and operation management, forming a replicable and standardized digital solution for the cultural museum industry, and promoting the solution of multiple pain points in the digital transformation of large comprehensive museums.

The project pioneers a digital twin theoretical system adapted to the entire life cycle of cultural museums, builds an integrated digital twin technology base with layered classification and cloud-edge-end collaboration, constructs a "management + service" dual-wheel-driven unified platform ecosystem, forms a multi-level standard system covering international, national, and industry levels, and outputs Chinese solutions for digitalization of cultural museums.

Triple Digital Propositions of the "Forbidden City"

Comprehensive cultural museum institutions like the Palace Museum have multiple functions of cultural relics protection, cultural and tourism services, and operational management. There are four core shortcomings: Ancient buildings and cultural relics lack a full-area high-precision real-time preventive monitoring and early warning system; Traditional exhibition and guidance are limited by time and space, making it difficult to meet immersive and personalized visit needs; Various business systems are independent of each other, with prominent data islands and insufficient intelligent auxiliary decision-making capabilities; Cultural relics display forms are limited, and the value of a large number of collections cannot be presented three-dimensionally.

Based on this, the case carries out research around the following directions: constructing a digital twin theoretical paradigm exclusive to cultural museums; breaking through multi-source heterogeneous data and building a unified twin data-base; overcoming high-precision AI virtual restoration technology for cultural relics and ancient buildings; developing multi-terminal, multi-user virtual-real fusion intelligent interaction systems; building an integrated digital twin platform and implementing full-scenario demonstrations.

Building a "Twin" for the Palace Museum in the Digital World



Cross-Terminal First-Person High-Fidelity Virtual Tour of the Hall of Mental Cultivation



The project builds a technical architecture of "one body, two sides, dual-wheel drive" integrating five elements: physical entities, multi-source data, digital twins, technical engines, and twin services.

The database innovates the "three-dimensional, four-category, three-level" organization model, covering three types of objects, namely cultural relics, space, and audiences, integrating four types of data, including monitoring and business, and adapting to different applications according to three levels of granularity including full-area, central axis, and single buildings. Twin modeling adopts a layered AI strategy. Full-area lightweight models support macro management and control, 3D Gaussian Splatting technology quickly reconstructs large sites, and PBR component-level fine modeling achieves realistic rendering of cultural relics. The interaction engine relies on 5G cloud-edge-end collaboration and SCAXR multi-user XR architecture, integrating Web AR, AI digital humans, and cloud tour technology. The unified platform supports intelligent management and protection internally and provides immersive services such as virtual tours and intelligent guides externally.

The project follows a six-stage closed-loop advancement and completed the full-chain implementation from theory to platform in three years, exporting the complete set of solutions to units such as Yungang Grottoes Research Institute.

Four Keys to Making Cultural Relics "Come Alive"

Model innovation breaks the system fragmentation status quo with a unified platform, forming an intelligent management closed loop of monitoring, early warning, and decision-making internally, and building a multi-level immersive public service matrix externally, which enable collaborative operation of management and services. Through technological innovation, the project achieves systematic AI modeling production, improving modeling efficiency by 80%, taking into account three types of modeling needs: large-scale scenes, complex sites, and fine cultural relics. Lightweight cross-



Digital Twin Application Service Platform of The Palace Museum



Large-Space VR Virtual Tour of the Three Rare Treasures Chamber in the Hall of Mental Cultivation

terminal interaction technology lowers equipment thresholds and supports multi-person cloud real-time linked tours. Theoretical innovation jumps out of simple 3D visualization and establishes a data-driven, dynamically evolving full life-cycle digital twin theoretical system for cultural museums. Standard innovation leads participation in 7 international and domestic industry standards at all levels, builds a complete digital twin construction evaluation specification, and forms a replicable "Palace Museum model" of demand-oriented, framework-led, platform-first, and standard-cured.

Full-Domain Effectiveness from Monitoring and Early Warning to Cloud Tours

In terms of protection, all-factor dynamic monitoring builds a closed loop for cultural relics management and protection. Management shifts from experience-driven to data-intelligence-driven, and passenger flow prediction and environmental early warning avoid cultural relics damage risks in advance. Economically, cloud virtual tours and digital research expand new cultural tourism formats, greatly improving user stickiness. AI modeling and unified data middle platform reduce modeling and operation and maintenance costs, driving cooperative enterprises to achieve technology transformation and revenue growth. Socially, VR/AR experiences break the time and space limitations of venues, achieving cultural inclusiveness for rural schools and overseas exhibition halls. The results have been displayed at national digital exhibitions many times and implemented in multiple provinces. Leading the formulation of international standards enhances the international voice of Chinese cultural heritage digitalization.

From the Palace Museum to the World: The Next Stop of Digital Twins

The project continues to iterate in three phases: 2026 to 2027 to improve data governance and platform security; 2028 to 2029 to expand multiple application scenarios such as virtual curation and emergency management and control; and by 2030, build a sustainable iterative standard and international interoperability system. Technically, continue to optimize high-precision collection and deep integration of multi-business data to create predictable and collaborative operational digital twins. In terms of resources, stabilize interdisciplinary R&D teams, ensure funds through multiple channels, and establish a data hierarchical authority management mechanism. Meanwhile, prevent and control four types of risks, such as surveying and mapping data compliance, copyright, and computing power costs, deepen international standard cooperation, and continuously promote the complete solution to various cultural museum heritage sites in China.



2025 Jingdezhen Handicraft Porcelain Industry Sites



Jingdezhen Handicraft Porcelain Industry Sites Digital Interpretation Project

002

Applicant Institution

CONSERVISION (Beijing) Cultural Consulting Co., Ltd.; Jingdezhen Municipal World Cultural Heritage Nomination Office

Participating Institution

Jingdezhen Ceramic Culture Tourism Group; Tencent SSV Digital Culture Lab

This case innovatively constructs an integrated digital interpretation system of "academic research as the foundation, VR-MR-AR layered display, AI data base, and public collaborative participation", solving the problems on the digital display operation and maintenance of large-scale handicraft heritage sites with large time and space spans, scattered points, and difficulty in on-site interpretation. The project establishes an academic translation mechanism of "real data-scientific model-digital presentation" to preserve the cultural core of heritage. Layered application of VR/MR/AR technology realizes macro-narrative of full-area heritage and precise on-site interpretation of archaeological sites. It also builds an AI multimodal data base with supporting intelligent guides and public inspection platforms, forming a new model of multi-party collaborative protection by government, enterprises, and the public, providing a replicable digital activation solution for scattered archaeological cultural heritage sites.



Project Distribution Map

"Unintelligible" Archaeological Sites and "Inaccessible" Remote Heritage Points

Jingdezhen was a world-class porcelain-making center from the 10th to 19th centuries, with nearly 2,000 hectares of handmade porcelain industry remains across 5 major areas and 45 heritage points. The farthest distance between raw material production areas and the core town is 50 kilometers, retaining the entire industrial chain of material collection, porcelain making, and trade. Currently, digital displays of similar large-scale scattered cultural heritage face three pain points: Emphasize cool technology and light basic academic research, which leads to insufficient excavation of historical and cultural connotations; lack native site information, which reduces the matching accuracy of digital content and archaeological scenes and makes it difficult for the public to understand strata and ancient kiln technological processes; lack overall planning in the early stage, with shortages of funds and manpower for later operation and maintenance, and a single display form with declining attractiveness, which makes long-term sustainable operation difficult.

Based on this, there is an urgent need for a comprehensive digital solution that balances academic rigor, on-site visual interpretation, long-term operation and maintenance, and participation of social forces.

Four-Layer Technical Architecture and Full-Format Implementation Path

The project builds a complete technical system of "academic support layer-VR/MR/AR technology application layer-AI database layer-public participation service layer". The academic layer relies on multi-field experts, intangible cultural heritage inheritors, and national-level scientific research topics



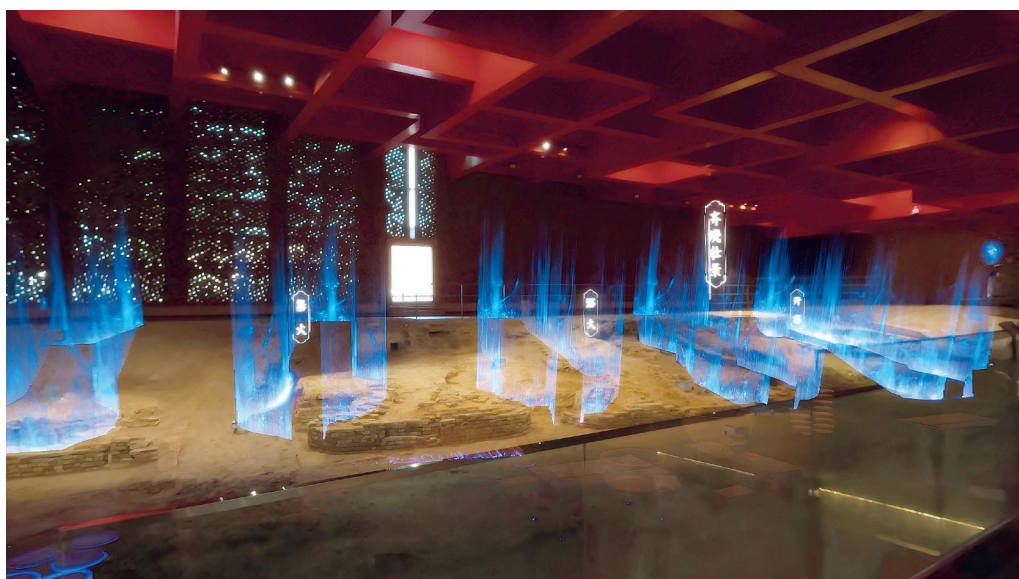
Project Concept: Content Construction Based on "Scene Shaping"



MR Multimedia Interactive Equipment for Gouyan Shang Kiln Workshop

to ensure content rigor. The VR layer builds a unified industrial narrative framework for the entire region. The MR layer achieves centimeter-level virtual-real superposition restoration at archaeological sites. The AR mini-program connects all heritage points, integrating guidance and online inspection functions. The AI base precipitates multimodal digital assets and outputs intelligent guides and robot inspection products. Self-developed LBVR large-space walking and rendering pipeline supports large-scale same-scene roaming, and 60 Apple Vision Pro are deployed on a large scale to create a thousand-square-meter site MR immersive system, achieving second-level repositioning and dynamic switching of ancient kiln strata; Centimeter-level VPS mapping AR mini-program covers 67 site scenes. A ceramic heritage multimodal dataset has been built relying on large models, with conversational AI companions and autonomous navigation guide robots put into use. Service extension provides audience-segmented bilingual intelligent explanation and research experience services for tourists, opens ceramic literature and archaeological 3D data retrieval services for scientific research groups, and opens the "Digital Guardian" inspection task participation entrance for the general public, building a channel for public-wide participation in protection.

The project completes full-format digital implementation at one time, building 1 set of VR, 5 sets of MR, 1 set of AR mini-program and a complete AI intelligent system, fully covering 45 heritage points, among which 3 core scenic spots operate for a fee, and the rest are all free open. For remote mine-type field heritage points, relying on AR mini-programs to achieve lightweight visual interpretation of sites without fixed venues, simultaneously supporting primary and secondary school research courses. In the continuous operation stage, expand the ceramic multimodal database, iterate multilingual AI guides and expand the deployment scope of intelligent robots; improve the volunteer operation system, and establish a quarterly update and annual evaluation closed-loop management mechanism. In 2026, VR/MR miniature experience versions will be produced to appear at the World Heritage Conference, and simultaneously hold an international forum on digitalization of cultural heritage to export standardized display paradigms externally.



Screen Recording of MR-VisionPro Equipment — Northern Foothill Site of Imperial Kiln Factory

Dual Breakthroughs in Model and Technology

Model innovation pioneers the three-layer linkage architecture of "AI database + intelligent cultural tourism application + public participation", centrally building a general ceramic digital asset library to avoid repeated digital construction at each heritage point, and linking technology enterprises, scientific research institutions, and social volunteers for collaborative operation, filling the institutional gap in long-term protection and social participation of large-scale scattered heritage.

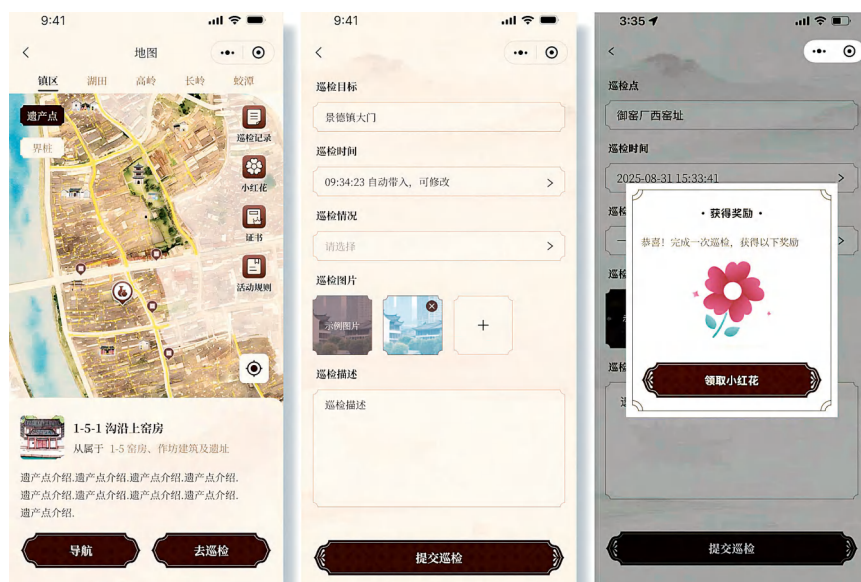
Multiple technological breakthroughs have been achieved, including the world's first large-scale deployment of 60 Apple Vision Pro at a thousand-square-meter archaeological site supporting centimeter-level MR virtual-real fusion, the industry's largest site AR scene matrix, China's first multimodal AI data set for handicraft cultural heritage, a full-link digital technology solution that integrates embodied intelligent robots and large model dialogue guides, and a systematic interactive digital expression of ancient kiln firing processes relying on national ceramic firing scientific research results.

Multi-Dimensional Effectiveness of Protection, Economy, and Society

In terms of protection and interpretation, the full-area digital system opens up the narrative of the complete porcelain industry chain. MR centimeter-level restoration solves the display bottleneck of "unintelligible" archaeological sites, and standard academic translation tools provide scientific support for in-depth interpretation of heritage value.

Economically, the revenue of core fee-based projects can cover their own operation and maintenance costs and feed back digital public welfare projects such as AR mini-programs. Digital experience products effectively drive the increase of scenic spot passenger flow.

Socially, it achieves visual popularization of remote field heritage points and supports regular research



AR Inspection Operation of "Digital Craftsman Guardian"

at 8 primary and secondary schools. The AR mini-program has accumulated more than 50,000 users, and the VR/MR core projects have received more than 5,000 visitors. Three basic ceramic databases have been built with 276 academic materials. The "Digital Guardians" have completed tens of thousands of public inspections to build a stable heritage protection community, promoting heritage protection from single government management to multi-party co-governance.

Technology Upgrade and Model Promotion Blueprint

In terms of technology upgrading, expand multimodal ceramic digital assets and improve knowledge graph semantic retrieval; participate in the formulation of industry standards for the digitalization of handicraft heritage. AI companions expand multilingual and dynamic route planning, and expand the deployment scope of guide robots.

In terms of scenario extension, in 2026, launch miniature digital experience products internationally and hold an international forum, promoting the complete set of layered digital models to other scattered and archaeological cultural heritage sites.

In terms of guarantee mechanism, continue to deepen the long-term operation model of "fee-based public welfare", establish a data hierarchical classification management mechanism and clarify the copyright ownership of digital assets, sign long-term maintenance and iteration agreements with technology manufacturers to cope with hardware technology iteration risks, and improve intellectual property contract clauses to avoid copyright disputes.

龙门石窟 残损及流散文物 数据聚合3D打印巡展

复位合璧 华光再光——龙门石窟流散文物数据聚合成果专题展
山水有清音——龙门石窟流散文物复位成果专题展

一叶一菩提——龙门石窟流散文物复位成果专题展
梵境双辉——龙门石窟与灵山胜境艺术对话展

3D Printing Touring Exhibition of Aggregated Data on Damaged and Dispersed Cultural Relics from the Longmen Grottoes

003

Applicant Institution

Longmen Grottoes Academy

Participating Institution

Luoyang Museum; Xinyang Museum; Anyang Museum; Wuxi Lingshan Museum; Nanjing Qixiashan Grottoes Academy

Relying on technologies such as 3D digitization, 3D printing, and VR/AR, this case solves the problems of restoring damaged statues of Longmen Grottoes and the physical return of overseas scattered cultural relics, and achieves full-area dissemination of digital protection results of cultural relics through a series of touring exhibitions.

The project builds a full-chain digital restoration technology system, breaks through the barriers of physical cultural relics return, and achieves virtual "reset and reunion"; Creates a touring exhibition model of "unified theme + localization", and expands cultural communication channels through online and offline linkage; Integrates academic research, technological restoration, and public education, taking into account preventive protection of cultural relics, cultural communication, and patriotic education, providing a replicable paradigm for digital activation of damaged and lost grotto cultural relics.

The Pain of Incompleteness of Millennium Grottoes

After more than 1,500 years, the damage to statues of Longmen Grottoes stems from natural weathering and historical theft and chiseling. In modern times, more than 780 niches and over a thousand statues have been stolen and lost at home and abroad. Currently, there are three major pain points in exhibition and utilization: the theft and chiseling process causes permanent incompleteness of statues; overseas scattered cultural relics are restricted by regulations and collection status, making physical return and reset difficult to implement; limestone statues are severely broken, and in-situ comparison and restoration cannot be completed only by pictures. Traditional protection and display methods have obvious shortcomings, and digital technology is urgently needed to open up the entire process of protection, restoration, and communication.

Digital Technology Makes Broken Fragments "Head and Body United"

The project builds a complete technical framework of "divisional data collection—3D modeling virtual restoration—multi-media activation display", forming a characteristic model of "data aggregation".



Revive the Glory of Lost Cultural Relics: Digital Reconstruction for Lost Cultural Relics in Longmen Grottoes

The project is advanced in three phases: The first phase (basic data construction) successively carries out high-precision digital collection of key caves of Longmen Grottoes, exquisite statues in the courtyard, and damaged and scattered cultural relics, using technical means such as 3D laser scanning, structured light scanning, and multi-image photogrammetry to preserve high-precision, permanently retainable precious original data of cultural relics. The second phase (academic research and technological transformation) is based on rigorous academic research and historical old photos, integrating 3D digital technology, traditional sculpture technology, color detection and analysis, scientific and technological archaeology, and artistic reproduction, successively completing the digital

reset of multiple damaged and scattered cultural relics such as Gaoshu Niche in Guyang Cave, the "Most Beautiful Guanyin" in Wanfo Cave, the life-size Amitayus Buddha on the north wall of Fengxian Temple, the Picture of Empress Wenzhao Worshipping Buddha in Binyang Middle Cave, Guanyin Bodhisattva and Heavenly King in Huoding Cave, and Cross-legged Maitreya Bodhisattva in Guyang Cave, achieving key technological breakthroughs such as virtual restoration of damaged cultural relics and restoration of caisson ceiling paintings in Binyang Middle Cave, and transforming the results into "head and body united, reset and reunited" 3D printed exhibits and immersive interactive devices. The third phase (series of touring exhibitions implementation) takes Luoyang Museum as the first stop, extending to Xinyang, Anyang, Wuxi, Nanjing and other places, adjusting exhibition focus according to local cultural characteristics, forming a standardized touring exhibition operation model of "unified theme + localized expression".

Making Cultural Relics "Come Alive" in the Exhibition Hall

Concept innovation interlinks the exhibition with the historical narrative of cultural relics damage, taking into account the scientific research value of cultural relics and patriotic cultural narrative. Technological innovation pioneers a complete set of digital reset technology for damaged and scattered cultural relics. The point cloud registration algorithm solves the problem of precise matching of damaged pieces. 3D printing and VR/AR break through the barriers between grotto sites and exhibition halls. The exhibition innovatively adopts a narrative combined with the timeline, the world map, and the comparison of old and new photos, concentrating on the debuts of multiple digital restoration results and intuitively presenting the process of cultural relics loss and its digital return. In terms of communication innovation, it builds a matrix of traditional media and short video new media, sets QR codes in the exhibition hall to expand online content, and synchronously spreads digital achievements on multilingual platforms at home and abroad.



Ethnic Fusion, Digital Revival: An Exhibition on Art Dialogue and Digital Rebirth of Grottoes from Jiankang to Luoyang, Stone Sculptures at Qixia Hill, Nanjing

From Exhibition Halls to the Cloud: Radiation and Appeal of Touring Exhibitions

In terms of protection, digital archiving and virtual reset of multiple core lost cultural relics have been completed. With 3D printed replicas replacing the original cultural relics in touring exhibitions, it can reduce the risk of original object transportation loss and build permanent digital archives of grotto cultural relics. In terms of communication, the offline series of touring exhibitions have received nearly one million viewers in total, with online exposure exceeding 50 million times across the network, and it has been reported by more than 60 media at home and abroad. Multiple exhibitions and projects have been rated as provincial and national excellent cases of cultural tourism digitalization, and public exhibition satisfaction reaches 92%. In terms of social education, through the comparison of the original state of stolen cultural relics and digital restoration results, it intuitively shows the connection between national fortune and cultural fortune, becoming a carrier of cultural confidence and patriotic education, and supporting social education activities such as clay sculpture and painting to promote grotto culture into campuses.

From Longmen to China: A Replicable Digital Restoration Paradigm

Technically, the entire process of 3D collection, virtual restoration, physical replication, and interactive display is suitable for the protection of damaged and scattered cultural relics in various grottoes nationwide. In terms of collaboration, the cross-institutional collaboration model has promotion value by linking research institutes, universities, museums, and media together to form a closed loop of "academic research—technology R&D—exhibition implementation—public education". In terms of touring exhibitions, "unified theme + localized adjustment" takes into account standardization and regional characteristics, adapting to cross-regional and cross-type digital cultural relics touring exhibitions. In the future, more efforts will be made to cooperate with universities to tackle algorithms to improve cultural relic matching efficiency and connect with collectors at home and abroad to expand the database of lost cultural relics, expand domestic touring exhibitions along the Silk Road and overseas digital thematic exhibitions, develop 3D printed cultural creativity and AR guide mini-programs to promote the integration of cultural and tourism industries, and establish digital copyright and transnational cooperation intellectual property control mechanisms to ensure the long-term sustainable development of the project.



Twin Radiance of Buddhist Realms: Art Dialogue Exhibition of Longmen Grottoes & Lingshan Buddhist Scenic Area

The project replaces scattered and independent databases with a multi-tenant ecosystem, and the unified data model takes into account full-area standardization and independent management of single institutions; Innovates the modular archive description system to add agent and geographic warehouse modules, improving the full-level information description of archives; Integrates technologies such as knowledge graphs, AI, IIIF multimedia storage, and intelligent chatbots, taking into account archive management, data interoperability, and public retrieval; Establishes an AI metadata traceability mechanism to achieve explainable and accountable technology applications, providing a standardized implementation paradigm for national archive digital integration.

Fragmented Archive System Trapped in the "Digital Tower of Babel" Dilemma

For decades, Italian archives have adopted the "separation model" and digital particularism, with each institution independently building systems, forming a large number of fragmented platforms. Each database has redundant data and inconsistent semantic standards, and user retrieval experience



is fragmented; Traditional systems only focus on high-level archive institution descriptions, lacking fine-grained single document information records; The binary division of archive creation subjects and custody subjects cannot completely sort out the relationships between people, institutions, and families related to archives; Archive text descriptions are disconnected from the physical storage location of warehouses, resulting in low warehouse management and retrieval efficiency; Old system data formats are incompatible, making cross-institutional and cross-library data migration difficult; Manuscript handwritten materials cannot be searched by keywords, and duplicate entities and garbage data accumulate in large quantities; AI applications lack decision traceability records, making it difficult to guarantee the academic rigor of archives.

Based on this, there is an urgent need to complete the integration of national archive resources relying on unified architecture, standardized models, and intelligent tools.

From Decentralization to Unification: "One Cloud" of National Archive

The system deeply integrates the national cultural heritage infrastructure I.PaC, and builds a five-layer progressive technical system of "data—model—storage—semantics—intelligence", allowing archive institutions scattered across the country to converge on the same "cloud". The basic data layer unifies the general data model and central authoritative document standards with a multi-tenant architecture. Each archive institution has an independent exclusive tenant space, achieving a balance between unified control of the whole domain and independent operation of institutions. The model description layer, on top of the unified data model, constructs a modular archive description model covering full-level information from the top-level archive architecture to single document units, adding "agent" entities to completely sort out the relationships between individuals, families, and organizations related to archives, and equipped with a terrain warehouse module to bind archive metadata and entity storage coordinates. The multimedia storage layer relies on the SaaS multimedia repository Teca Multimediale equipped with IIIF high-definition player to achieve high-definition integrated reading of digital images and multimedia files linked to archive metadata. The semantic interconnection layer, supported by knowledge graphs and linked open data bases, follows the RiC-O international ontology



Platform Website

standard, converts archive data into linked open data, and opens up the path of data interoperability between archives, libraries, and museums. The intelligent application layer integrates HTR handwritten text recognition to enable manuscript keyword retrieval, AI algorithms complete data cleaning and entity merging, and the Teseo intelligent chatbot provides professional consultation combined with archive regulations, while mandatorily retaining complete metadata records of AI training and algorithm decision-making processes to ensure traceable and explainable technology applications. The five-layer architecture progresses layer by layer from bottom to top—the data layer lays the foundation for governance, the model layer standardizes description standards, the storage layer ensures resource readability, the semantic layer achieves cross-domain interoperability, and the intelligence layer empowers precise services—together constituting a complete technical closed loop for unified management, storage, retrieval, and service of national archives.

The project is iteratively launched in batches and simultaneously completes massive historical data migration: In July 2024, the core management system Sia and virtual reading room were launched in the pilot release phase, selecting three institutions in Florence, Milan, and Venice to pilot and verify the feasibility of multi-tenant and modular description models; From January to September 2025, the legacy system migration phase completed large-scale data migration of old Sias and Siusa systems through the standardized ICAR Import channel and is compatible with third-party commercial archive software such as Arianna 4 and xDams; From the end of 2025 to early 2026, the multimedia resource migration phase unified the migration of digital archives, retrieval portals, and supporting digital objects to the Teca multimedia repository to complete full system integration. Up to now, more than 140 archive institutions have accessed the system, and after full operation, it will carry millions of archives and 180 million digital objects.

Dual Leaps on Model and Technology

The model innovatively abandons scattered independent databases and uses a unified multi-tenant ecosystem to solve the long-term problem of data fragmentation, establishes a full-level description framework for archives to connect macro collection architecture and micro single document records, innovates the description logic of archive subjects to break the binary limitation of creators and keepers, and pioneers the archive geographic warehouse linkage module to achieve precise digital management of warehouses.

Based on knowledge graphs, technological breakthroughs have been achieved by linking open archive data and connecting to international standards to achieve cross-cultural institution data interoperability, integrating HTR, data disambiguation AI, and regulatory intelligent Q&A robots, establishing an AI full-process metadata traceability mechanism to standardize the ethics and rigor of intelligent applications in the field of cultural heritage, and adopting SaaS multimedia storage and IIIF standards to achieve seamless reading of high-definition digital archives.

New Picture of National Archive Integration

In terms of resource management, unified standards eliminate data redundancy and semantic conflicts. The multi-tenant model balances overall control and independent operation of institutions. Millions of archives and hundreds of millions of digital objects achieve centralized standardized storage.

The warehouse coordinate linkage module greatly improves archive retrieval and internal management efficiency.

In terms of data interoperability, following the RiC-O ontology standard to form linked open data achieves cross-domain linkage of archives, libraries, and museum resources. Old system and third-party software data can be migrated and accessed in a standardized manner. In terms of service efficiency, handwritten archives support keyword retrieval, intelligent robots lower the threshold for public archive queries, and virtual reading rooms rely on IIIF to achieve convenient reading of high-definition multimedia archives.

At the industry demonstration level, establishing AI traceable and accountable implementation norms sets industry standards for intelligent applications of cultural heritage digitalization, completing the transformation of archive management from scattered and fragmented to integrated collaboration. In the future, we will continue to optimize the knowledge graph-linked data model and iterate AI recognition and data disambiguation algorithms, improve the professional Q&A capability of the Teseo chatbot, continue to complete the access of remaining archive institutions and expand cross-regional and transnational archive data interconnection applications, continuously improve the ICAR standardized data interoperability channel and update metadata traceability specifications, ensuring long-term secure storage and compliant intelligent application of massive archives.





005

Deutschlandmuseum Berlin - The immersive history museum

Applicant Institution

Ravir Film

Participating Institution

Deutschland Museum DM GmbH (Robert Rückel), Creative Studios Berlin

Based on the intersection of museum exhibition, film production, and immersive media, this case creates a full-sensory immersive historical viewing system, solving the problem of insufficient attractiveness of traditional static exhibitions to teenagers and groups with weak historical knowledge.

The project pioneers an embodied narrative model, relying on spatial scenes, multi-sensory special effects, and audience interaction to lower the threshold for understanding historical content; builds a mixed media modular production system, balancing historical rigor and visitor experience and adapting to short-term urgent projects; forms a migratable and standardized immersive exhibition hall implementation process, providing a complete reference plan for digital upgrading of cultural venues at home and abroad.

Two Thousand Years of History Squeezed into Two Hours: A Content Compression Battle Against Time

Traditional museums rely on monotonous presentation formats of text display boards and static exhibits for historical popularization, resulting in a limited audience reach. To fully present two thousand years of German history for audience in a two-hour visit, the German Berlin Museum faces multiple prominent problems: simplifying the narrative without tampering with historical facts; various media such as live-action shooting, animation, interactive installations, and sound and smell special effects are difficult to integrate, and a little carelessness will risks fragmenting the exhibition content and disrupting the audience's experience; the construction period is only four months, and the entire process from concept design to on-site delivery is compressed in an extremely short time, urgently needing an efficient collaborative production mechanism.

The core demand of the project is to create an immersive historical experience adapted to multi-age diverse audiences, open up the multi-media integrated narrative link, and establish a standardized production plan for high-quality immersive spaces with short cycles, so that historical knowledge can achieve maximum communication effect within a limited time.

From Script to Space: A Multi-Sensory Narrative Technology System

The project interlinks different stages of historical scenes via the visiting route, successively creating immersive spaces such as primitive Germanic forests, medieval halls, World War I trenches, 1920s cities, and post-war apartments, matching light and shadow, sound effects, smells, and spatial sound fields to restore the atmosphere of the times. Meanwhile, the system supports practical projects such as trench periscopes, historical broadcasts, Gutenberg printing presses, and retro dance interactions, allowing audiences to complete historical learning through personal participation, achieving the transformation from passive viewing to active experience.

Technically, the system adopts corresponding production methods according to narrative scenes, relies on archive image digital matte painting to build basic historical environments, and uses 3D modeling to restore complex spaces. By combining green screen live-action shooting and virtual environment synthesis with 2D animation and Pepper's Ghost optical imaging, it matches spatial stereo audio and multi-sensory systems while taking into account production costs, picture realism, and rich visual layers.

In terms of production, it adopts the core logic of dual-line parallel and continuous feedback linkage between narrative R&D and visual production. In the early stage, historians are engaged to control historical facts, and storyboard scripts and animation previews are output to test spatial rhythm and audience circulation paths in advance. The system builds a distributed collaboration architecture of the



1920s Urban Spaces and Post-War Apartments



Vintage Dance Interaction

core team and long-term cooperation outsourcing network, with animation, graphic, sound effect, and technical teams advancing simultaneously and unified delivery standards, ensuring the four-month short construction period is completed.

At the model level, it breaks the disciplinary barriers of film, animation, and spatial design, integrating live-action images, interactive equipment, and exhibition hall space into a unified narrative system, solving the long-standing fragmentation problem of multimedia exhibitions.

How the "Four-Month Construction Period" Extreme Challenge Wins Against Time

The project is promoted as a whole at one time, and the whole process is divided into four sections: academic research and audiovisual concept design, storyboard preview creative verification, parallel production of multi-media content, and on-site installation and debugging. Relying on modular task splitting, new personnel can quickly access, and defects are identified in advance through early previews to reduce later rectification investment.

The entire process is highly versatile and can be replicated and applied to various immersive transformation projects of cultural venues. Immersive narratives greatly lower the threshold for acquiring historical knowledge, adapting to diverse groups such as children and overseas tourists. The venue was rated "Best Attraction of 2026" and became an internationally popular cultural tourism landmark. The project verifies the implementation advantages of pre-preview, cross-team parallelism, and multi-technology combination, providing an industrialized template for immersive exhibition in cultural museums, exploring the mixed development model of combining museum education functions with film narrative and themed spaces, and providing practical examples for the transformation of a new generation of cultural venues.



Visitor Interaction

Global Promotion Blueprint of Immersive Narrative

Technically, it will continue to iterate the existing content in the museum and optimize the sound effect system, launch multilingual audio guides, transform the Enlightenment Era Exhibition Hall with radar and camera sensor interactive equipment, and build a real-time interactive space of thinkers' light and



Indoor Ambience Scenes

shadow linkage relying on Unreal Engine.

In terms of scenarios, it exports mature production systems externally, develops 360-degree ring screens and multi-screen narrative spaces, jointly develops dance-integrated VR innovation projects with partners, and jointly develops panoramic immersive environments integrating sound, light, temperature, and smell with universities.

In terms of promotion, it adopts the operation mode of a core team and external cooperation network, raises funds through multiple channels such as project entrustment, scientific research funds, and joint production, expands domestic and foreign immersive cultural museum projects, and in the long term, builds immersive narrative into a sustainable, standardized, and replicable general transformation model for cultural venues.

In terms of risk guarantee, to avoid the three major risks of high media integration difficulty, complex technical systems, and tight construction period in advance, efforts have been made on modular task design, early prototype testing, and stable collaboration teams, ensuring the stability and controllability of the entire process from concept to implementation.



VR Large Space Experience Project at Archaeological Ruins of Liangzhu Ancient City

006

Applicant Institution

Hangzhou Liangzhu Ancient City Tourism Development Co., Ltd.

Participating Institution

Zhejiang Teemax Cultural Technology Co., Ltd.

This case creates the world's first full-sensory, VR immersive and interactive project of Liangzhu Ancient City. Relying on digital technologies such as VR large space, cloud rendering, and multi-sensor positioning, it completes high-precision digital restoration of Liangzhu civilization and builds a new model of immersive cultural tourism experience.

The project empowers cultural activation with technology, relying on archaeological data to achieve millimeter-level high-precision restoration of the ancient city scene five thousand years ago, transforming abstract Liangzhu culture into an interactive immersive experience. It also innovates a composite cultural tourism operation model to break the single ticket economy, forming a closed loop of "VR experience + cultural creativity + leisure consumption" and creates standardized and replicable digital cultural tourism products, establishing a "academic + art + technology" collaboration mechanism with the ability to output and promote across venues and regions.

How Five-Thousand-Year-Old Civilization Fits into VR Headsets

As a world cultural heritage, Liangzhu Ancient City's existing display and communication system has three prominent pain points: The display form is static and single, relying on display boards, physical objects, and static models that cannot vividly restore the urban pattern and ancestors' life of the ancient city, and it is difficult for tourists to establish deep emotional resonance; the threshold for cultural connotation communication is high. Abstract civilization values such as the rice farming water conservancy, the jade ritual system, and the early state system are difficult for traditional explanations to make young people and international tourists understand, and cultural communication penetration is insufficient; Cultural tourism integration transformation is weak. Existing business formats lack immersive experience consumption scenarios, and the derivative value of cultural IP is insufficiently explored, making it difficult to match the current experiential cultural tourism consumption demand.

Therefore, it is urgent to break through time and space limitations with digital technology and transform archaeological achievements into interactive experiences perceivable by the public under the premise of strictly adhering to archaeological academic rigor.



How Archaeological Data Become "Walkable" Virtual Ancient Cities

The project builds a four-layer technical framework. The data layer is based on archaeological survey data and authoritative academic achievements to ensure the historical accuracy of digital content; The modeling layer uses 3D Gaussian splatting reconstruction and dynamic rendering technology

to generate hundreds of millions of high-fidelity digital models, completely restoring core site scenes such as palaces, royal tombs, and workshops. The interaction layer optimizes the GF-ORB-SLAM2 algorithm, integrating multi-sensors to achieve millimeter-level multi-person synchronous free walking interaction in a 400-square-meter space. The computing power layer adopts cloud rendering with lightweight 4K headsets, reducing wearing burden and ensuring high-definition smooth immersion effects.

The project is implemented in four phases: Academic planning phase (2 months) to form an interdisciplinary team of scholars, screenwriters, and technicians, sort out archaeological materials and establish the core narrative thread of "Covenant of Divine Patterns"; digital content production phase (5 months) to restore site scenes, characters, and jade props with high precision in modules, and complete plot animation production; venue technology integration phase (3 months) to build an 840-square-meter comprehensive venue, deploy positioning base stations and cloud rendering equipment, and set up experience, cultural creativity, handicraft, and leisure commercial spaces in zones; iterative operation phase (from July 2025) to launch trial operation on Liangzhu Day, collect audience feedback and continuously optimize the plot, interaction, and venue visitor circulation paths. Cultural expression innovation shifts from static restoration to civilization activation, integrating cores such as the water conservancy, the ritual system, and the rice farming into plot interactions to make abstract culture intuitively perceivable; operation model innovation bids farewell to single tickets, integrating VR experience, cultural and creative retail, and tea and coffee catering to build a complete cultural tourism consumption chain; narrative technique innovation adopts time-travel plot narrative integrating fantasy elements, fitting young people's aesthetics and strengthening emotional resonance. The exhibition mode innovatively uses regular VR main exhibitions with quarterly special temporary exhibitions to continuously produce young communication content.

Immersive Experience Stimulates Cultural Identity

Socially, the project has been rated as a provincial-level cultural gene activation project in China and a benchmark scene for digital cultural tourism in Hangzhou, and has been specially reported by mainstream media agencies such as People's Daily and China Media Group. The total number



of impressions of related topics on Douyin and Xiaohongshu exceeds 15 million, making the project ranked first in the local top VR experience list, and becoming an important carrier for youth study trips. Immersive experiences allow the audience to become "participants" rather than "bystanders", allowing them to personally experience the water conservancy system, palace patterns, and jade ritual system of 5,000 years ago through virtual roaming, transforming abstract civilization values into perceivable body memories, effectively strengthening the public's cultural identity and confidence in Chinese civilization.

The project verifies the effectiveness of the "academic + art + technology" tripartite collaboration mechanism, providing a replicable practical path for the transformation of cultural heritage from content of static exhibitions to tools for immersive activation.

From Liangzhu to the Whole Country: Technical Confidence in Standardized Replication

The project's practices have formed multi-dimensional replicable experiences, adhering to the two driving forces, namely "cultural IP" and "digital technology", with content as the foundation and technology serving cultural expressions. It has built a tripartite collaboration mechanism of "scholars' checks, artistic creativity, and technology implementation" to balance historical rigor and experiential fun. Modular product development standardizes and encapsulates scenes, interactions, and operation processes, supporting rapid localization adaptation for venues across the country. The diversified communication matrix establishes credibility with authoritative media and achieves spontaneous fission communication through social platform KOL marketing.

In the future, in terms of technology iteration, it will upgrade lightweight headsets and implement eye tracking and gesture interaction, and introduce AIGC to reduce content production costs. In terms of







scenario expansion, it will customize content for multiple versions such as diversion, research, and parent-child, and output standardized VR projects to 2 to 3 museums/other cultural organizations nationwide in 2026 and improve the regular research base system. In terms of the export of cultural content, it will rely on the Belt and Road Initiative to link overseas cultural centers and museums for multilingual digital touring exhibitions from 2026 to 2027.

In addition, in terms of risk response, for technology iteration risks, it will collaborate with multiple hardware manufacturers to establish a mechanism for remote regular upgrade and maintenance of systems; for off-site replication acclimatization, it will reserve localized content space and recruit local experts to optimize content, and implement the "one place, one policy" approach for operation; for insufficient repurchase risks, improve tourists' repurchase willingness with fixed quarterly temporary exhibitions and festival-exclusive experiences supporting membership and package ticket systems.



Chinese Inscription Database

007

Applicant Institution

Gulian (Beijing) Digital Media Technology Co., Ltd.

Based on the pain points in terms of the preservation of Chinese stone inscriptions, including scattered resources, high sorting difficulty, and limited communication and application, this case involves an innovatively developed new model of activation and utilization of stone carving cultural heritage with academic standardized sorting as the foundation, digital intelligent technology as the core, and knowledge services and digital publishing as the carriers. The project focuses on four core problems: resource aggregation, literature collation, achievement transformation, and cultural communication, and has completed the implementation of the entire chain involving technological architecture, platform construction, publishing model, and service ecosystem in an innovative manner, providing a benchmark paradigm for the digital transformation of ancient books and literature nationwide.



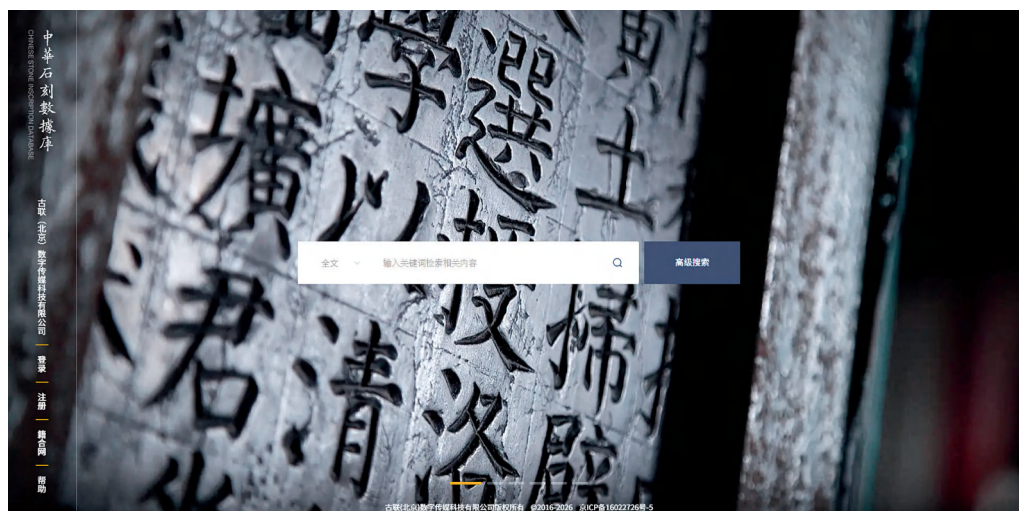
Triple Dilemmas of Digitalization of Stone Inscriptions

Currently, there are three prominent shortcomings in the digitalization of stone inscriptions. Resource aggregation is difficult. Stone carving cultural relics and rubbing materials of past dynasties are scattered across regions and institutions (museums and other cultural institutions) and private collectors at home and abroad, with tough-to-tackle data barriers and serious resource fragmentation, lacking an integrated, authoritative resource base. The threshold for sorting relevant inscriptions is extremely high. Stone carving categories are complex and diverse, coupled with various calligraphic styles, containing a large number of variant characters and blurred and damaged characters. Traditional digital means cannot complete high-precision interpretation and standardized collation. Specifically, achievement iteration and publicity lag behind. Traditional paper publishing has problems such as long cycles, slow updates, and inconvenient retrieval, making it difficult to match the dynamic iteration needs of new academic achievements.

The project carries out systematic research around four directions: resource aggregation, intelligent text processing, academic standard development, and digital publishing innovation.

Four-Layer Technical Architecture and Three-Stage Implementation Path

The project pioneers a four-layer exclusive technological architecture integrating "collection and processing, data management, knowledge services, and terminal application". It has established a standardized system for stone carving data, unified metadata, and collated rules and storage specifications, covering a full range of resources such as images of rubbings, ancient characters, and academic catalogs. Relying on self-developed ancient book OCR and intelligent punctuation technologies, it has built an ancient rare character processing system, overcoming the technological problems of display and retrieval of uncoded ancient book characters. Adopting a B/S architecture marked by front-end and back-end separation, and standardized API communication, it innovatively realized cross-database linkage of stone inscriptions and the general catalog database, and built a



Database's UI



Advanced Search Function

comprehensive service platform integrating intelligent sorting, precise retrieval, academic study, and dynamic publishing.

The project was implemented in three phases:

The first phase involved the investigation and survey of full-area stone carving resources, sorting out the survival status of resources by era, region, and category, and completing the centralized aggregation of massive scattered resources.

The second phase focused on core technological bottlenecks such as the interpretation of damaged texts and variant character processing, and, through the aid of the relevant experts, completed literature collation, sentence reading, and knowledge indexing.

The third phase was centered on improving intelligent service modules, establishing a dynamic update mechanism for academic achievements, absorbing cutting-edge research results in real time, and collaborating with universities and museums and other cultural institutions to promote application.

Four innovative breakthroughs include constructing a stone carving digital standard system of "academic rigor + digital adaptation"; iterating the exclusive AI recognition model for stone carvings, which is adapted to different fonts and damaged rubbing scenes; pioneering the "one-step" digital publishing paradigm of stone carving academic achievements, which smoothed the entire process of research, revision, and release; and innovating the intensive model of "general library + special topics" to realize the aggregation of scattered resources to a three-dimensional knowledge ecosystem. Through condensation, the project has formed a standardized methodology for the digitalization of ancient books, developed a collaboration mechanism of "expert scholarship + technology implementation", and formed a universal construction path adapted to ancient books, unearthed documents, and local cultural and historical resources.

Effectiveness of Both Resource Aggregation and Social Services

The project has cataloged more than 80,000 stone inscriptions and more than 80,000 images of



Page Showing Details of an Inscription

rubbings, building a large-scale, standardized digital collection resource library. The platform has adopted a dual-channel model of "direct sales" plus "agency", serving 32 official purchasing institutions and more than 600 trial institutions at home and abroad, forming a stable revenue system. Its intelligent text processing technology greatly reduces the cost of literature sorting, and the dynamic digital publishing model avoids the disadvantages of long cycles and difficult updates of traditional paper publishing, driving the upgrading of the industry chain involving ancient book digitalization and cultural and museum knowledge services. The platform greatly reduces the research threshold through functions such as graphic comparison, intelligent retrieval, and online study, helping the inheritance and development of the little-known specialized heritage studies of stone carvings. The product covers hundreds of universities and scientific research institutions at home and abroad, becoming an important digital carrier for the external communication of Chinese stone carving culture.

Three-Stage Blueprint Led by Quality Improvement and Boundary Expansion

The project has formulated a three-stage development plan of "quality improvement – boundary expansion – leadership". Specifically, from 2026 to 2027, iterate intelligent technology and improve data governance; from 2028 to 2029, expand public application scenarios such as smart research and cultural tourism experience; and by 2030, build a complete standard and intelligent service ecosystem for stone carving digitalization. In the future, the relevant stakeholders and practitioners will continue to develop core technologies such as exclusive AI large models for stone carvings, intelligent restoration of damaged rubbings, and knowledge graph visualization, promote the platform to upgrade from a data supply hub to a provider of intelligent knowledge services, continuously expand resource volume and improve multi-format cooperation ecosystem, strictly implement data security and copyright compliance management, deepen Sino-foreign academic communication and cooperation, and build a digital service benchmark for stone inscriptions with international influence.



Digital Exhibition of the Collection Hall of A Comprehensive Collection of Ancient Chinese Paintings

008

Applicant Institution

Zhejiang University Press

Based on the achievements of the national major cultural project "A Comprehensive Collection of Ancient Chinese Paintings" (hereinafter referred to as the "Collection"), this case, based on the actual work needs of protection, exhibition, publicity, and social aesthetic education of ancient calligraphic works and paintings, has formed through exploration a traditional cultural activation and utilization model of "technology empowering art, academia serving the public". Addressing real pain points associated with traditional calligraphic works and paintings, such as their preciousness and fragility, inability to be exhibited regularly, single exhibition form, and difficulty in benefiting the public as high-end academic resources, the project has opened up the complete chain of "academic sorting-digital transformation-public display-public sharing", forming a set of replicable, implementable, and promotable digital display and cultural communication paradigms for museums and other cultural institutions housing such calligraphic works and paintings.



How to Break the Dilemma of "Difficult to Store and Use" of National Treasure-level Calligraphic Works and Paintings

Currently, there are many common shortcomings in the protection, display and cultural publicity of ancient calligraphic works and paintings in China.

The conflicting needs of storage and use of cultural relics are prominent. Most handed-down ancient paintings are made of fragile materials such as paper and silk, with strict requirements for storage environment and exhibition conditions. They are therefore unable to be exhibited publicly for a long time. A large number of national treasure-level calligraphic works and paintings are stored and are not accessible to the public.

High-quality resources are scattered and fragmented. Handed-down paintings of past dynasties are scattered and collected in 263 Chinese and foreign museums and other cultural institutions, lacking a systematic and panoramic centralized display platform.

There are only limited exhibition experience modes. Traditional calligraphy and painting exhibitions mainly adopt static glass display cases and graphic and text explanations, with limited room for interactions.

The effectiveness of aesthetic education communication is insufficient. Research results of these cultural treasures are mostly professional publications, with recipients limited to those from academia. There are high thresholds for public access and few channels of publicity.

The project focuses on resource integration, digital empowerment, scenario innovation, and public-focused services to carry out systematic construction.



Immersive
Appreciation

Technological Leap from "Regular Viewing" to "Immersive Appreciation"

The project has built an integrated digital system of "display - interaction - guided tours - services" adapted to the characteristics of calligraphy and painting exhibitions. In terms of resources, relying on authoritative high-definition painting color proofs accumulated over more than 20 years of compilation of the Collection, as well as the self-developed 3D reconstruction technology of Zhejiang



Multi-User VR Experience

University, the members of the project have restored grotto murals and statues such as those from Dunhuang and Yungang with high fidelity, building a standardized digital resource library marked by excellent image quality, recyclability, and zero cultural relics loss. In terms of interaction, relying on 4K projection, spatial audio, and motion sensing equipment, the project has integrated MR, VR, and AIGC technologies to create immersive spaces for viewing paintings, realizing dynamic activation of static ancient paintings, scene reproduction, and virtual-real interaction. In terms of guided tours, it has facilitated the upgrade from the traditional static exhibition label mode, using QR codes, mini-programs, and audio guides as carriers, and integrating audio explanation, exhibit traceability, and route planning functions. In terms of services, relying on large model technology to iterate intelligent Q&A and scene explanation functions, it has been improving the venue smart service system.

The project follows the principle of gradual progress and iterative implementation. First, regular themed exhibitions were introduced to transform national academic achievements into stable and open public cultural resources, followed by deepening school-local collaborative content creation to develop characteristic content such as immersive light and shadow exhibitions and MR digital aesthetic education programs, and the promotion of grassroots-level inclusive services to bring lightweight digital exhibition items to campuses and communities. Finally, smart service capabilities were iterated to continuously optimize intelligent guides and scene interaction functions. Four innovative breakthroughs include using authoritative digital achievements to replace genuine exhibitions to achieve both protection and utilization, achieving experience upgrade from "viewing paintings" to "entering paintings" through 3D grotto restoration and virtual environment construction, interlinking famous paintings of past dynasties with thematic and systematic logic to completely present the inheritance context of Chinese painting art, and transforming professional academic achievements into exhibition experiences and aesthetic education courses that everyone can participate in.

From 45 Cities to 17 Countries: A Cultural Relay Across Time and Space

The project has fostered an open aesthetic education practice platform marked by cross-sector integration, and regularly carries out activities such as university co-creation campaigns and aesthetics study trips, effectively contributing to interdisciplinary practices and aesthetic education talent training. The project has been covered by reports of more than 30 central and provincial mainstream media outlets, with its brand influence continuing to improve. Currently, 70 touring exhibitions have been held in 45 cities in China, and 18 international special exhibitions have been carried out in 17 foreign cities, recording over 12 million visits. Premium digital exhibition items have been presented on platforms such as the World Internet Conference, and the total number of impressions of related topics exceeds 250 million, effectively enhancing the domestic publicity power and international influence of Chinese calligraphy and painting culture. Lightweight digital aesthetic education products continue to become part of grassroots civilization practices, campus aesthetic education, and public cultural life, delivering benefits of traditional Chinese culture to all through sharing.

Replicable "Industry-Academia-Research-Application" Collaboration Paradigm

During the implementation and operation of the project, a mature and feasible digital construction methodology has been formed. The project also led to the formation of a collaborative mechanism of "Industry-Academia-Research-Application", linking universities, venues, technology enterprises, and museums and other cultural institutions to achieve full-chain connectivity of academic research, technology transformation, content creation, and scenario-based application. Focusing on culture and leveraging technology for empowerment, it is based on the uncovering of traditional cultural connotations, developing lightweight and replicable digital products for aesthetic education and cultural tourism, and eliminating technology stacking and hollow formalism. It has established a multi-level



An Immersive Performance

linkage benefit model, and built a full-coverage and equalized public cultural service system with three modes: fixed exhibition halls, mobile touring exhibitions, and publicity for grassroots.

Long-Term Blueprint from the Collection to National aesthetic education

Closely following the deployment of China's national cultural digitalization and aesthetic education power construction, the project has formulated a phased long-term development plan.



Interior View of an Exhibition Hall

From 2026 to 2027, deepen school-local-museum collaboration, improve research practice, cultural and creative development, inter-museum linkage, and regular touring exhibition mechanisms, and enrich public aesthetic education supply.

From 2028 to 2029, continuously iterate digital immersive scenarios and launch multiple new digital exhibition projects, and improve the large model intelligent explanation service system.

By 2030, fully build a mature and widely influential platform of digital display, aesthetic education and popularization, and international communication for calligraphic works and paintings. In the future, the stakeholders and practitioners will continue to deepen the integrated application of culture and technology, incubate more lightweight and promotable digital cultural products, continuously expand domestic and foreign communication channels, and provide long-term support for the protection and utilization of traditional Chinese culture, the upgrading of national aesthetic education, and the exchange and mutual learning of Chinese and foreign civilizations.



Digital Display and Dissemination of Ancient Architecture in Shanxi

Applicant Institution

Shanxi Academy of Ancient Building and Painted Sculpture Fresco Preservation (Shanxi Ancient Architecture Museum, Shanxi Culture Relics Preservation Fund Management Center)

Participating Institution

National Museum of Classic Books; Harvard FAS CAMLab; Beijing Wutong Technology Co., Ltd.

This case focuses on the pain points of activation and utilization of immovable cultural heritage items and sites such as Shanxi ancient buildings, murals, and painted sculptures, and has innovatively developed a new digital display model of "high-precision digital collection + immersive interactive experience + national tour publicity". It has changed the status quo of "emphasizing archiving and neglecting application" in traditional cultural relics digitization, and targetedly solved core problems such as limited display of immovable cultural relics, idle digital resources, obscure cultural interpretation, and difficult cross-domain communication, building a digital system integrating protection, display, education, and publicity.



Exhibition's Poster

Dual Dilemmas of Cultural Relics That "Cannot Go Out" and Resources That "Cannot Be Used"

Currently, there are obvious shortcomings in the digital protection and utilization of immovable cultural relics in China.

Display of cultural relics subject to numerous restrictions: Ancient buildings, murals, and painted sculptures are fragile, and the original sites and items cannot support high-frequency visits. Off-site exhibitions can only display replicas and fragments, making it difficult to restore the original scenes and overall artistic style of cultural relics.

Low utilization rate of digital resources: Massive high-precision data remains unused for a long time and cannot be transformed into resources for exhibitions or public education programs.

Low effectiveness of cultural interpretation: The ancient building construction techniques and the artistic connotations of murals and painted sculptures are highly professional and obscure, and it is difficult for the public to truly understand the values of cultural relics through old-school static exhibitions.

The project carries out systematic research around four directions: digital restoration, immersive experience, value interpretation, and omni-channel publicity.

Technological Leap Path from Yongle Palace to Foguang Temple

The project pioneers a four-in-one full-chain technological system of "collection – reconstruction – interaction – presentation". Relying on millimeter-level laser scanning and visual algorithm modeling to complete high-precision data collection, it also leverages AI-powered texture restoration and



Large-Space VR Experience

dynamic activation technologies to restore details of faded and damaged parts of cultural relics. By integrating multiple technologies such as those of VR large-space immersion, virtual-real fusion projection, and multi-touch to create multi-sensory experience scenarios, the technological system continues to iterate and upgrade. With the national touring exhibition "Walking Shanxi" as the core carrier, characteristic digital exhibitions were launched in stages. Yongle Palace's "Guan Miao Ru Zhen" exhibition pioneered the AI-powered mural figure activation technology, completing the dynamic restoration of 286 deities in "Chaoyuan Tu" (a mural), relying on four-fold screens to present the grand scene of murals, and matching VR ink wash immersion theater to accurately reproduce the overall layout of Yongle Palace. The Xiaoxitian exhibition completely replicates the suspended sculptures of the Mahavira Hall at 1:1 through super-realistic modeling (with a polygon count of over 10 billion) and 16K high-definition maps, relying on real-time ray tracing technology to create movie-level VR immersion scenes, supporting gesture interaction and virtual dialogues with Buddhist masters. Guangsheng Temple is planned to open its first exhibition in 2026, and Foguang Temple and Nanchan Temple will be open to the public in 2027, forming a continuously advancing technological development path.

Replicable Paradigm of "One-Time Collection for National Tour Exhibitions"

Through condensation, the project has fostered a standardized and reusable paradigm. It has established full-chain technological specifications, and unified the standard processes of cultural relics collection, modeling, rendering, and exhibition, providing mature technological references for similar projects. The "one collection, multi-scene reuse" model was implemented to synchronously



A Scene Recreated Through 3D Modeling

use high-precision digital resources for archiving, exhibitions, popular science, and cultural creativity, completely solving the problem that immovable cultural relics cannot be displayed across regions. The project has also developed an interpretation system that balances academics and the public, transforming obscure professional knowledge with digital interaction, making ancient building art visible, playable, and understandable. The Yongle Palace exhibition series has completed six tour exhibitions nationwide, marked by a high resource reuse rate and sustainable operation. After the implementation of multiple ancient building exhibitions in the future, the "Walking Shanxi" touring exhibition series will be further strengthened.

Communication Effectiveness and Industrial Value of Breakthroughs in Publicity of Cultural Relics

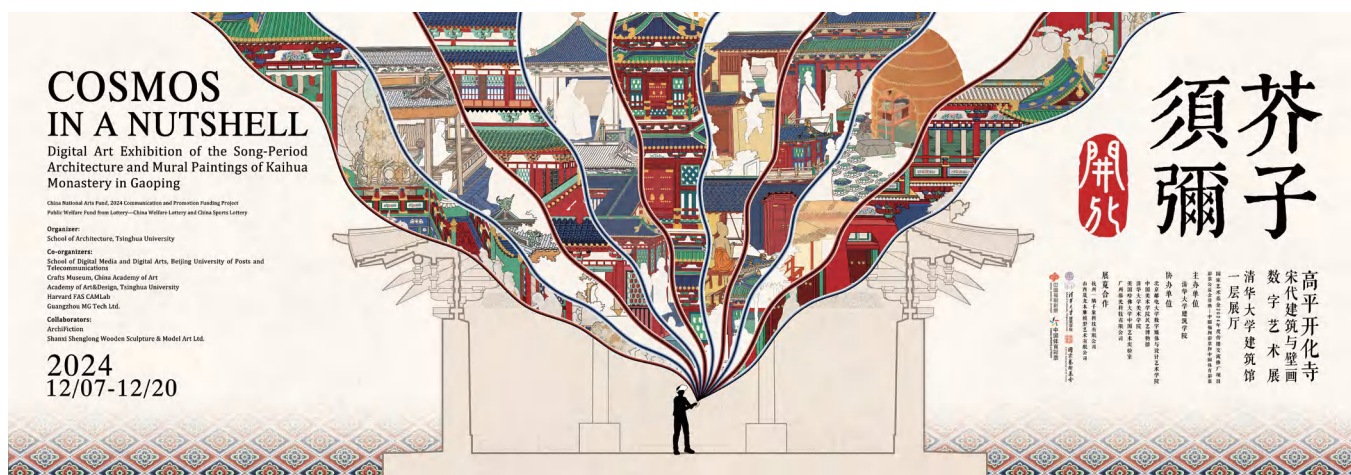
The number of monthly average visits of Yongle Palace's "Guan Miao Ru Zhen" exhibition has reached 60,000, and the ratio of the expenditure of tickets to that of creative cultural consumption has reached 2:1. The user conversion rate of core VR exhibition items far exceeds the industry average. The project has been covered in reports of more than 50 authoritative media outlets such as China Media Group, with the number of online impressions exceeding 100 million, gaining popularity through publicity on new media platforms. This project has completely broken regional barriers to achieve inclusive publicity of cultural heritage, allowing Shanxi's ancient building culture to gain popularity nationwide, while visitors from outside the province can immerse themselves in the charm of ancient building art. By translating professional academic content into popular immersive experiences, the project has effectively narrowed the distance between the public and cultural relics, especially stimulating young people's interest in traditional culture learning, providing high-quality demonstration for the activation and utilization of immovable cultural relics in China.



Visitors Viewing the Exhibition

Next Stop of Ancient Building Digitalization: Better Leverage of Technologies and Deep Cultivation of Cultural Intellectual Properties

The project will continue to deeply cultivate the field of ancient building digitalization. Technically, continuously optimize high-precision collection, AI cultural relics restoration, and mural dynamic digitalization technology; deepen the implementation of AR/MR technologies and intelligent interaction, and continuously improve the refinement and immersion of digital exhibitions. In terms of content, launch the Guangsheng Temple digital touring exhibition in 2026, and launch themed exhibitions of Foguang Temple and Nanchan Temple in 2027, continuously expanding the ancient building digitalization resource pool in Shanxi province. In terms of promotion, continue to strengthen the "Shanxi on Tour" (行走的山西) exhibition brand, build a standardized and replicable ancient building digital communication system, and promote the regular "going out" of fine cultural heritage in Shanxi. At the same time, establish an expert review system, full-link copyright protection, and regular operation risk control mechanisms, and continuously lead the high-quality development of digital protection and communication of immovable cultural relics nationwide.



COSMOS IN A NUTSHELL: Digital Art Exhibition of the Song-Period Architecture and Mural Paintings of Kaihua Monastery in Gaoping

010

Applicant Institution

Tsinghua University

To address challenges in temple architecture and mural integrated heritage protection and communication, based on the characteristics of cultural relics and public popular science needs, leveraging long-term academic accumulation and multidisciplinary digital technology, this case creates a new digital exhibition model of "academic foundation, space restoration, immersive experience, full-area communication". Addressing the common problems of fragmented display, obscure content, and emphasis on technology over content, the project abandons the traditional static single-point display method, promotes heritage display from single item presentation to overall spatial experience, from shallow technical display to deep cultural interpretation, forming a replicable and promotable digital revitalization path for murals in ancient buildings.





Exhibition Hall

Dilemma of Fragmented Display and "Hard-to-Understand" Murals

Currently, there are three typical problems in the digital display of murals in ancient buildings: The display system is fragmented; Most exhibitions lose track of the overall relationship between architecture, murals, environment, and traditional ritual paths. The exhibitions are mainly static displays, unable to restore the original spatial layout and cultural context of ancient buildings; High threshold for public communication. Murals in Kaihua Temple are ancient and complex. Coupled with weathering, fading and partial damage, they are hard for ordinary visitors to grasp their cultural connotations, resulting in limited effectiveness in popular science and public communication; Digital application puts the cart before the horse. Most projects blindly pursue visual immersion effects, lack solid academic support, fail to explore the deep value of heritage, and expose the common problem of emphasizing form over content.

The project systematically solves the above pain points through overall spatial restoration, popularization of academic content, and immersive experience upgrade.

Exhibition Framework: From Academic Research to Immersive Experience

The project adheres to the deep integration of academics and technology, builds a systematic digital protection and display system, and innovates a three-level progressive exhibition framework of "overall cognition—spatial experience—spiritual travel". Through multi-scale models and real scene images, the project comprehensively presents the temple's environment, architectural form, and panorama of the murals, and restores the original scene of ancient buildings with naked-eye mixed reality and immersive images, clearly showing the process of mural textual research and spatial restoration. Combined with CAVE immersion theater and multi-person VR interactive technology, the project restores the narrative scene of the Buddha world in the murals following the traditional clockwise circumambulation conventions to arrange the visiting route, allows the audience to immerse in the



Interactive Installations

hierarchical changes of spatial artistic conception, and builds an online cloud platform to realize online and offline linkage communication.

The project is steadily implemented in stages: Since 2015, basic work such as 3D laser scanning, high-definition photography, and color detection has been completed, and standardized cultural relics digital archives have been established; From 2017 to 2024, systematic study of the historical evolution, architectural form, and mural narrative logic of Kaihua Temple was done, consolidating the foundation of exhibition content; In 2024, relying on the support of the China National Arts Fund, the project transformed academic achievements into standardized digital exhibitions; From 2024 to 2025, exhibition tours were held at universities, art galleries, and public venues across the country, as well as in Canada and Brazil for international cultural exchanges, and achieved regular heritage communication through online platforms.

The project forms multiple core innovations, breaking the fragmented display mode to completely restore the overall spatial value of heritage, transforming obscure and professional knowledge into audience-friendly exhibition content with academic textual research as the core, adhering to culture as the foundation and technology as the tool to avoid blind technology stacking, and restoring the ancient ritual viewing circulation path to realize the transformation from passive viewing to immersive experience. At the same time, it follows the four-in-one practical method of "research, exhibition, teaching, and communication", which can be widely adapted to the digitalization of spatial heritage such as temples, grottoes, and gardens.

Collaborative Implementation of Touring Exhibitions, Online Tours, and Industry-Academia-Research Collaboration

Socially, the project has completed high-precision data preservation of Kaihua Temple's architecture, colored paintings, murals, and surrounding environments, established a complete digital archive, and provided scientific support for cultural relics monitoring, disease treatment, and repair protection.

Through domestic and international touring exhibitions and online VR tours, it breaks communication barriers of time and space, allowing niche Song Dynasty murals to go beyond Shanxi to the whole country and the world. At the same time, the project relies on its exhibitions to carry out regular teaching practice, public welfare lectures, and experience courses, popularize cultural knowledge on murals in ancient buildings and cultivate digital talents in culture and museum industries.

Economically, the touring exhibition is accompanied by multiple cultural formats such as study tours, cultural and creative products, and artistic interpretation, forming a sustainable cultural tourism operation model, effectively driving local cultural tourism consumption and enhancing regional cultural recognition. Through coordinated development with universities, technology enterprises, and cultural institutions and museums, the channel of industry-academia-research-implementation is opened up.



Exchange Activities

Building a Replicable Benchmark for Digitalization of Murals in Ancient Buildings

The project will continue to deeply cultivate the field of digital revitalization of murals in ancient buildings, steadily promoting technological upgrading, scenario expansion, and academic research. The project will continuously improve the cultural relics digital database, refine related information on architectural techniques, mural materials, and disease, deepen dynamic scene restoration, explore new technologies such as AI-assisted restoration and multi-user collaborative interaction, and summarize industry general display specifications. It will also expand domestic and international touring exhibition scenarios, develop lightweight mobile exhibition versions, upgrade online platform functions, deepen school-local integration and academic openness, and gradually promote mature experience to other cultural heritages such as Yongle Palace, Mogao Caves, and classical gardens. At the same time, it will improve data security, copyright protection, and technological upgrading risk control mechanisms, adhere to the cultural ontology and reject excessive technology stacking, and strive to build a replicable and promotable benchmark for digital revitalization of murals in ancient buildings.



中国云南
澜湄国家跨境语言大模型

项目背景
澜湄国家跨境语言大模型项目旨在保护和传承澜湄国家跨境语言文化，通过数字化手段建立语言资源库，实现语言数据的共享和传承。



项目意义
澜湄国家跨境语言大模型项目具有重要的文化价值和现实意义。它不仅有助于保护和传承澜湄国家跨境语言文化，还能通过数字化手段建立语言资源库，实现语言数据的共享和传承，为澜湄国家跨境语言文化的传承和发展提供有力支持。

项目成果
澜湄国家跨境语言大模型项目取得了显著成果。项目团队成功构建了澜湄国家跨境语言大模型，实现了澜湄国家跨境语言数据的数字化存储和共享。项目成果得到了澜湄国家跨境语言文化传承和发展的高度重视和肯定。

澜湄国家跨境语言大模型技术架构图

澜湄国家跨境语言大模型技术架构图展示了该模型的分层结构，从数据层到应用层，涵盖了从数据采集到最终应用的全过程。

数据层 (Data Foundation)

- 澜湄国家跨境语言数据源 (Lancang-Mekong Cross-Border Language Data Sources)
- 澜湄国家跨境语言数据清洗 (Lancang-Mekong Cross-Border Language Data Cleaning)
- 澜湄国家跨境语言数据存储 (Lancang-Mekong Cross-Border Language Data Storage)

核心能力层 (Core Capability Layer)

- 澜湄国家跨境语言识别 (Lancang-Mekong Cross-Border Language Recognition)
- 澜湄国家跨境语言合成 (Lancang-Mekong Cross-Border Language Synthesis)

应用层 (Application Scenario Layer)

- 澜湄国家跨境语言文化传承 (Lancang-Mekong Cross-Border Language Culture Inheritance)
- 澜湄国家跨境语言文化保护 (Lancang-Mekong Cross-Border Language Culture Protection)
- 澜湄国家跨境语言文化发展 (Lancang-Mekong Cross-Border Language Culture Development)

项目背景

澜湄国家跨境语言大模型项目旨在保护和传承澜湄国家跨境语言文化，通过数字化手段建立语言资源库，实现语言数据的共享和传承。

项目意义

澜湄国家跨境语言大模型项目具有重要的文化价值和现实意义。它不仅有助于保护和传承澜湄国家跨境语言文化，还能通过数字化手段建立语言资源库，实现语言数据的共享和传承，为澜湄国家跨境语言文化的传承和发展提供有力支持。

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Lancang-Mekong Cross-Border Language AI Large Model

011

Applicant Institution

Yunnan Endangered Language and Culture Communication Co., Ltd.

Participating Institution

Unimind; Shanghai Biren Technology Co., Ltd.; Dream Corps

This case focuses on the digital rescue, protection and dynamic revitalization of cross-border low-resource ethnic languages in the Lancang-Mekong River basin. The six Lancang-Mekong cooperation countries are home to various cross-border ethnic groups and have complex dialect systems. Most cross-border ethnic languages lack standardized writing systems and standardized corpus reserves, making them typical low-resource endangered languages. Traditional language protection mostly relies on extensive modes such as paper archives and scattered audio recordings, with structural shortcomings including a weak data foundation, lagging technical adaptation, and limited forms of preservation.



Recording Site

Relying on few-shot learning technology of artificial intelligence large models, the project builds an AI digital knowledge service platform integrating intelligent translation, text creation and voice interaction through multilingual corpus collection, proofreading and modeling, to realize digital preservation, intelligent application and regular dissemination of cross-border ethnic languages.

The "Endangerment" Dilemma of Low-Resource Languages

Cross-border ethnic languages in the Lancang-Mekong basin face multiple dilemmas. Most languages have no standardized writing system and lack standardized corpus reserves. Traditional protection relies on paper archives and manual translation, with a weak data foundation and limited forms of preservation. Long-standing language barriers not only hinder regional people-to-people exchanges and the upgrading of cultural and tourism integration, but also cause inheritance faults of niche ethnic languages and unbalanced development of regional digital culture. In response to the above pain points, the project explores digital application paths adapted to low-resource cross-border languages based on few-shot learning technology, completely eliminating the drawback of traditional protection that "emphasizes archiving but neglects application".

Four-Layer Technical System and Few-Shot Learning Path

Based on the endowment of language resources and the reality of cross-border development in the Lancang-Mekong basin, the project innovates a four-layer integrated technical system of "data foundation—core capabilities—demonstration system—scenario application".

At the data level, it systematically collects more than 20 dialects and cross-border ethnic language resources, completes batch corpus annotation, manual proofreading and classified archiving, and builds the first standardized, multimodal cross-border low-resource language dataset in the region.



Multilingual Translation Dialogue System

In terms of its core technology, relying on large model algorithms, it gets rid of the strong dependence of traditional models on massive annotated data. It can complete high-precision text translation, smart text creation, and speech recognition and synthesis based on a small number of samples, greatly lowering the threshold for digitization of niche endangered languages.

Following the implementation path of "corpus co-construction—model R&D—system construction—scenario implementation", the project has now launched six mature demonstration systems covering six core languages: L ü chun Hani, Baihong Hani, Akha Hani, Wenshan Miao, Southeast Asian Miao, and Southeast Asian Akha languages. They support functions such as real-time text translation and smart speech synthesis, and can be applied well in scenarios including cross-border governance, intangible cultural heritage inheritance, cultural and tourism promotion, ethnic education and rural e-commerce.

写一首白宏话的歌曲

白宏哈尼语翻译助手

《Haqniq Yoqmal》（哈尼人的路）
——Beeqhongq Saziiq Hxalbaq（白宏语民歌）

【A 段】自然与祖先

(慢板，模仿山风与流水节奏)
Xilva a neelma↑, dov lal↓...
(这里的太阳，升起来了...)
Milcaq tavq a, aqbol lei ml↓
(大地上，祖先在劳作)
Albol alpavq, leeq gaol val↑
(树叶飘落，时光流逝)
Qeilkeel e gal, maq cal sal↓
(稻谷的路，永不消失)

(拟声词过渡)
Hil... hil... (风声) | Ziiq... ziiq... (雷声)

Dialogue Powered by Large Language Models

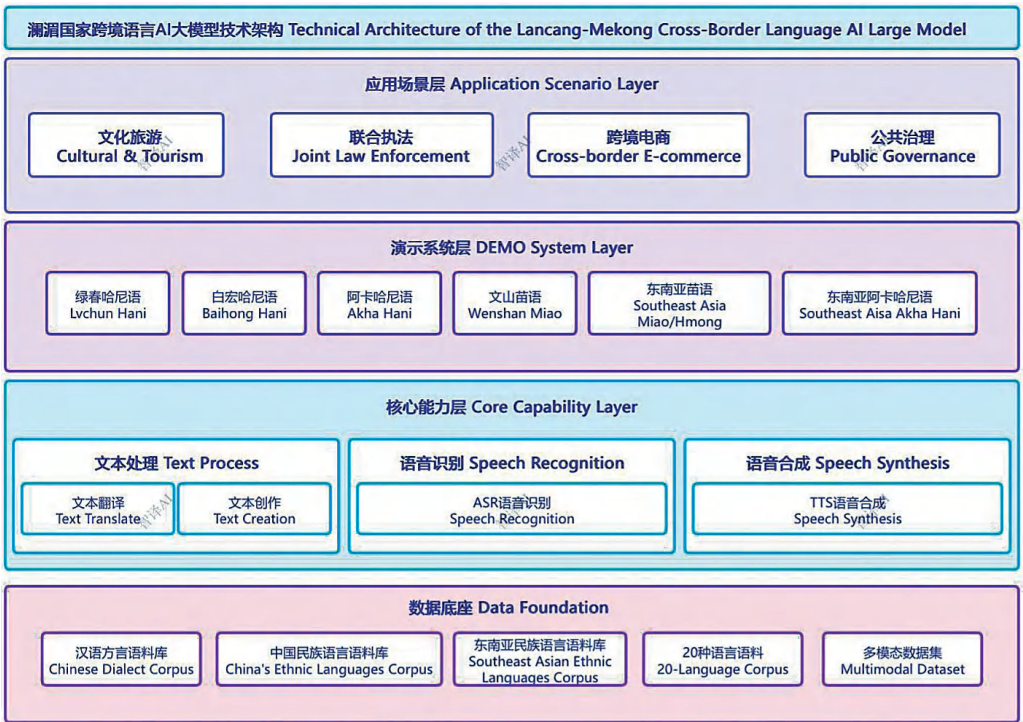
Three-Dimensional Effectiveness of Corpus, Model and Cross-Border Implementation

The project has built a standardized corpus resource pool covering more than 20 cross-border ethnic languages, launched six sets of professional AI service systems, with a cumulative token consumption of 300 million times. The overall service efficiency and translation accuracy surpass the traditional manual mode.

In 2026, the project team went to the mountainous areas of Chiang Rai, Thailand to carry out cross-border implementation applications. For the first time, it relied on AI technology to accurately complete the translation and cultural output of books of local Akha ethnic group, filling the industry gap of digital communication of cross-border low-resource languages.

The platform has become an important support carrier for ethnic language teaching and academic research in multiple universities in the province, effectively making up for the shortage of professional talents and teaching resources. The intelligent interconnection function completely breaks through cross-border language barriers, and effectively empowers key work such as cross-border law enforcement cooperation, grassroots governance and security early warning.

Relying on the mother tongue digital service system, the project helps border people conveniently access digital education and cultural tourism and e-commerce resources, narrowing the regional digital divide. The explored AI revitalization model for low-resource languages with few-shot learning can provide a Chinese solution for the protection of more than 6,000 low-resource languages worldwide.



Technical Architecture of the Lancang-Mekong Cross-Border Language AI Large Model

From Minority Languages to Large Models: The Next Stage of Digitalization of Languages in Lancang-Mekong Basin

In the future, the project will continue to strengthen its efforts in the digital protection and intelligent services for cross-border low-resource languages.

In terms of resources: it will continuously expand cross-border language resources such as Zhuang and Yao languages to consolidate the data foundation.

In terms of technologies: it will optimize the few-shot AI algorithm model, improve the quality of speech synthesis and translation accuracy, and advance the construction of AI large model research centers and computing power centers for low-resource languages.

In terms of real-world scenarios: it will continue its effort in core areas such as cross-border governance, ICH activation, cultural tourism and e-commerce, and ethnic education.

In terms of collaboration: it will deepen the co-construction and sharing of resources among universities and scientific research institutions in the basin, relying on the Lancang-Mekong cooperation mechanism.

At the same time, a whole-process risk control mechanism covering dynamic corpus update, standardized data authorization and strict content review will be established to continuously polish a standardized and replicable benchmark for cross-border language digital services.



AI驱动 的 开放叙事 游戏

入画·清明上河图： 走进汴京，成为画中人

贩夫走卒到达官贵人，从市井小儿到耄耋老者，从街头贩花女到深闺官眷——世相百态，芸芸众生，她们凝固在绢本上已近千年。现在，你可以进入每一位人物的人生，探索他们的出身、职业、关系与夙愿，在桥头、茶肆、舟楫与坊巷之间做出细小却真实的选择。有宿命，亦有偶然，还有那些被命运重新照亮的时刻。

开始游戏

人物画廊

关系网络

故事分享

制作人员



012

Into the Painting: Along the River During the Qingming Festival

Applicant Institution

Hong Kong Institute for the Humanities and Social Sciences, The University of Hong Kong

Participating Institution

Centre for Quantitative History, The University of Hong Kong; Faculty of Arts, The University of Hong Kong

This case focuses on realizing dynamic deduction, scene reconstruction, and interactive activation and display of the static ancient painting *Along the River During the Qingming Festival* based on artificial intelligence multi-agent technology. At present, the digital construction of painting, calligraphy works and other cultural relics in China generally stays at the display stage of high-definition scanning and static reproduction, with prominent problems such as limited exhibition forms, weak public participation, and superficial cultural interpretation. The daily life of thousands of ordinary townsfolk in ancient paintings has long been ignored by grand historical narratives, and it is difficult to vividly present them through traditional exhibition means. This project breaks through the technical limitations of traditional static display, transforms the thousand-year-old static ancient painting into an interactive, deducible and immersive dynamic historical scene, and deeply revitalizes the inherent narrative value of the ancient painting.

Three Limitations of the Digitalization of Painting, Calligraphy Works and other Cultural Relics

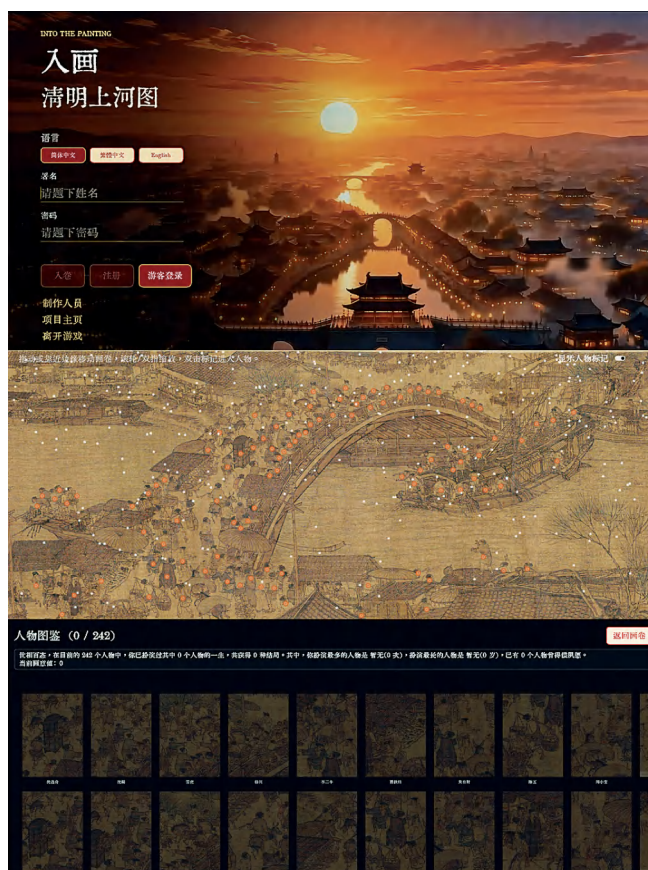
At present, the digitalization of painting, calligraphy works and other cultural relics generally has three pain points:

First, limited exhibition forms. Most projects only complete the static preservation of the visual form of cultural relics, which can only support passive viewing by the audience, and cannot restore the comprehensive urban social structure and dynamic people's livelihood showcased in the ancient paintings.

Second, weak public participation. The traditional digital exhibition is dominated by one-way viewing, and the audience cannot deeply participate in content exploration.

Third, superficial cultural interpretation. The life trajectories, interaction logic and hidden narratives of thousands of characters in the painting cannot be effectively released, and the deep historical and cultural value is difficult to spread.

In response to the above pain points, the project relies on AI simulation and multi-agent collaborative technology to promote the transformation of traditional painting and calligraphy heritage from static specimen preservation to dynamic immersive communication.



Game Interface

Build Dynamic Historical Scenes with Multi-Agent System

The project builds an AI-driven historical simulation and open narrative interaction system, and constructs a dynamic Bianjing urban market scene that can evolve in real time, interact freely and iterate independently.

Technically, it integrates a multi-agent system and a large language model architecture, features the characters in the painting as independent intelligent units, matches each character with exclusive



Game Interface

identity background, behavior logic, action goals and social rules, and simultaneously builds a full state model covering character relationships, scene environment and event evolution.

The system is equipped with two core modules: narrative generation and dynamic update. Without preset fixed plot scripts, it can independently deduce character behaviors according to the user's real-time operations, generate multiple plot branches, and form an open historical narrative system with high freedom and unique experience for each user.

The project follows the implementation logic of "data foundation—model construction—mechanism iteration—scenario implementation":

First, complete the detailed analysis of the full view of the ancient painting, character annotation, identity tracing and background filing, and build a complete character-specific database;

Second, build a multi-agent collaborative simulation framework, optimize the core mechanisms of real-time deduction, intelligent narrative and state update;

Finally, develop a front-end immersive interactive system to support users' independent decision-making and immersive participation in the narrative.

The project has achieved all-round innovative breakthroughs:

Upgraded from mechanical reproduction of fixed content to smart generation of AI dynamic content; Upgraded from a single top-down viewing perspective to multi-character immersive first-person experience; Upgraded from isolated static pictures to social interpersonal interaction and urban ecology deduction; Upgraded from passive viewing to an interaction experience to enable users to actively participate and co-create independently. At the same time, it forms a standardized path of "image analysis—character modeling—network construction—intelligent simulation—interactive narrative", which can be widely adapted to digital revitalization of various cultural heritages such as ancient paintings, historical documents and archaeological remains.

Experience Upgrade from "Viewing the Painting" to "Into the Painting"

Since the trial operation of the project, it has achieved remarkable results in expanding cultural influence to broader audiences, optimizing public experience, and carrying out heritage popular science education.

In terms of online demonstration: the innovative interactive dynamic display mode has aroused widespread social attention. The depth of user interaction and the heat of spontaneous communication continue to rise, effectively solving problems of dull traditional ancient painting viewing and low acceptance among young audiences.

In terms of experience: it completely innovates the ancient painting viewing mode. With immersive forms of dynamic deduction, multi-line narrative and character substitution, it guides the audience to deeply enter the real scene of urban life in the Northern Song Dynasty, and intuitively perceive the urban layout, commercial formats and folk customs of the Song Dynasty.

In terms of cultural communication: focusing on the individual fate and daily work of ordinary people, the project gives tangible form to fragmented yet vivid folk history, and greatly broadens the dimensions for expressing traditional culture. In terms of educational application: it introduces new exploration-style popular science education scenarios, and provides brand-new digital teaching tools for historical research as well as popularization of painting and calligraphy art.

Blueprint for Technology Enhancement and Scenario Expansion

In the future, the project will continue to enhance the integrated field of AI + cultural museum digitalization:

Technically: continuously optimize the multi-agent collaborative deduction algorithm, improve the panoramic scene state modeling system, and enhance the logic of AI-generated content and the stability of real-time interaction.

In application: expand the mature ancient painting revitalization framework to cultural resources such as ancient paintings and calligraphy works, historical documents and archaeological remains, build a general and reusable dynamic activation system for cultural heritage, and deepen large-scale implementation in smart cultural museum exhibitions, campus aesthetic education and digital cultural and creative industries.

In the medium and long term: build an open and shared R&D platform to empower scientific research teams and cultural and creative creators to carry out further development and content co-creation.

At the same time, a full-dimensional risk prevention and control as well as content standardization system will be established. Through multi-level content verification, standardized copyright traceability and scientific narrative boundary management, it will balance interactive fun and historical and cultural seriousness, avoid excessive entertainment interpretation, and continuously build a benchmark for AI revitalization of traditional culture with excellent technology, rigorous content and replicable experience.



Bringing Characters in Ancient Books to Life: Shuihudi Bamboo Slips Digital Exhibition

013

Applicant Institution

Research Center for Legal Culture of Shuihudi Qin bamboo Slips, Yunmeng

Participating Institution

Hefei Panshi Intelligent Technology Co., Ltd.; Anhui University

Based on the core resources of bamboo and wooden slips, this case breaks through the limitations of traditional static exhibitions, and innovatively builds an immersive digital exhibition system, realizing the transformation of ancient book cultural relics from "static specimen viewing" to "dynamic historical narrative".

The Qin bamboo and wooden slips from Shuihudi, Yunmeng are first-class cultural relics in China, selected as one of the "Top 100 Archaeological Discoveries in the Past Century". They record the legal system, grassroots governance and social livelihood of the Qin Dynasty. Among them, the slips inscribing the Qin Dynasty's legal system are the earliest and most complete existing written legal documents in China, and the wooden slip letters from garrison soldiers are the earliest known battlefield letters in China.



In response to the prominent pain points of ancient book exhibitions—ancient characters are difficult to identify, content is difficult to understand, and history is difficult to empathize with—the project relies on the core resources of Shuihudi Qin slips to build a three-dimensional narrative exhibition system, promotes the innovative revitalization and inheritance of the thousand-year-old Qin slip text heritage, and provides a replicable example for the digital activation of grassroots ancient books.

The "Unintelligible" Dilemma of Ancient Document Exhibitions

At present, the exhibition mode of ancient documents is generally rigid, dominated by static display and simple translation. The Shuihudi Qin slips are written in archaic Qin clerical script with obscure and professional texts. Ordinary audiences lack knowledge on this, so it is difficult for them to understand

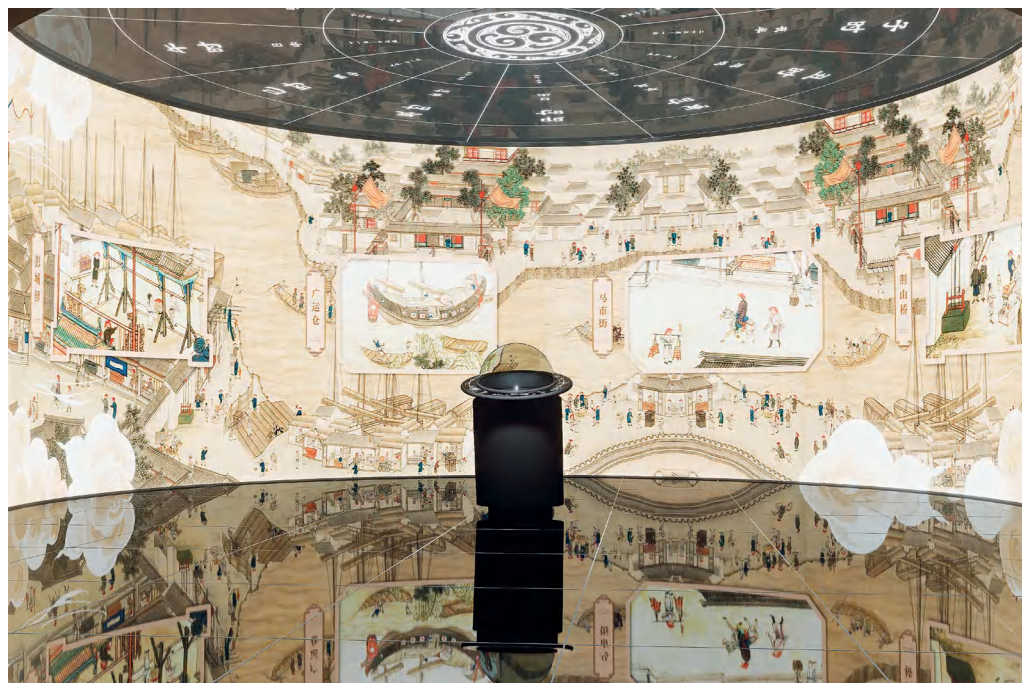


Exhibition Hall

the legal system and governance logic of the Qin Dynasty, and they cannot perceive the personal fates and sentiments of the era behind the texts. As a result, these precious ancient documents suffer from insufficient dissemination of cultural value, weak public awareness and obstacles to inheritance. Abandoning the homogeneous misunderstanding of the cultural industry that emphasizes technology over content, the project adheres to content-oriented, technology-empowered and experience-first principles. It innovatively constructs a three-dimensional narrative system of "professional value, character stories, and era panorama", and explores a new replicable model for digital activation of ancient books adapted to grassroots cultural museum venues.

From Legal Provisions to Urban Life: Two Halls Tell the Story of the Qin Dynasty

The project adopts a layout of "one site, two halls". With the Shuihudi archaeological site as the core, it is divided into two major exhibition areas: the Law Hall and the Character Hall.



Immersive Circular Screen Exhibition Hall

The Law Hall focuses on the legal culture of the Qin Dynasty. Relying on digital exhibition items such as intelligent query of legal texts, somatosensory interaction of height-based criminal responsibility, and restoration of the "cave theft" judicial case, it transforms obscure Qin legal provisions, judicial investigation procedures and grassroots governance systems into intuitive and interactive immersive experiences, vividly demonstrating the rigor and advancement of Qin legal civilization.

The Character Hall focuses on the vivid individuals behind the ancient books. Centering on the real life stories of "Xi" (喜, a Qin clerk) and garrison soldiers "Heifu" (黑夫) and "Jing" (惊), it restores daily

grassroots governance, border garrison scenes and patriotism of the Qin Dynasty through projection sand tables, immersive theater, heaven-earth linkage interaction, and digital display of family letters, endowing the cold ancient book characters with warmth and vitality.

The two halls jointly create characteristic scenes such as arc-screen sand tables, folk custom fold-screen theaters, and interactive evaluation systems, fully presenting the changes of Qin territory, institutional innovation and urban livelihood features.

The project breaks through the limitation of single cultural relic display and realizes the three-dimensional integration of legal value, character emotion and era panorama. Based on the condition of venues, it uses mature lightweight digital technology to accurately empower cultural narratives, solves the problem of ancient book activation and communication at low cost and high efficiency, and has outstanding industry adaptability and promotion value.

Cultural Breakthrough and County Vitality Behind the Data

Since the project opened for operation in November 2025, the average daily passenger flow of the exhibition hall has increased from less than 10 people before opening to more than 150 people, with a single-day peak exceeding 800 person-times. It has received nearly 30,000 visitors in total and 130 batches of various special visits. The audience stay experience effect far exceeds that of county-level exhibition halls of the same level.

The number of online AI bamboo slip interactions reached 430,000 times, and the utilization rate of offline interactive equipment exceeded 85%, effectively lowering the threshold for ancient book interpretation. The audience's recognition of the cultural value of Qin slips increased from 37% to 91%, truly achieving the core effect of "seeing objects, seeing people, seeing history".



Exhibition Wall

The project has been reported more than 50 times by national media such as People's Daily and Xinhua News Agency, with a total network communication volume of over 18.4 billion times, bringing county-level national treasure cultural relics to the whole country and overseas.

At the same time, a hierarchical research system has been built, receiving more than 60 batches of research groups from primary and secondary schools, universities, and public security/procuratorial/judicial systems. Customized courses are tailored for different groups, taking into account youth aesthetic education and law popularization, university academic research, and legal education for public officials, fully releasing the social education value of ancient books.

Long-Term Operation Mechanism and Path to Enhance International Influence

In the future, the project will continue to deepen the field of digital activation of ancient books, adhering to digital empowerment, in-depth connotation excavation, cultural and tourism integration, and long-term operation.

In digital construction: build a cloud-based digital resource library of bamboo slips, complete high-definition archiving and multilingual translation, and build a full-domain shared online exhibition hall to break the time and space limitations of offline exhibitions.

In research education: optimize the hierarchical curriculum system for all age groups, regularly carry out activities of Qin slip culture entering campuses, communities and government agencies, and build a systematic heritage education matrix.

In brand upgrading: fully promote the application for Memory of the World Heritage, improve materials in line with international standards, carry out cross-civilization comparative studies of the rule of law, and enhance the international influence of Chinese legal civilization.

In international communication: prepare for the International Forum on Qin Slip Culture, produce multilingual communication content, and deepen international cultural exchanges.

At the same time, a robust mechanism for content updating, copyright management, and diversified funding will be established to steadily mitigate operational and technological iteration risks, and continuously refine a replicable and scalable benchmark for the digital activation of grassroots ancient books—thereby supporting the long-term inheritance of fine traditional Chinese culture and its global dissemination.



014

Black Myth: Wukong Encounters Shanxi

Applicant Institution

Xinhuanet

Participating Institution

Xinhua News Agency Shanxi Branch; Black Myth; Shanxi Pengfei Group Co., Ltd

This case focuses on the application of immersive display and interactive experience technology. Relying on the official genuine authorization of Black Myth: Wukong, it creates a digital art exhibition integrating the dual IPs of "games + ancient architecture".

Relying on the traffic of top digital IP and mature digital technology, the project promotes the in-depth integration of Shanxi ancient architecture resources and game digital assets. It balances cultural relics protection and cultural activation through immersive interactive exhibitions, breaks the communication barrier between cultural museum resources and young people, and explores a new path for the innovative transformation and development of cultural heritage.

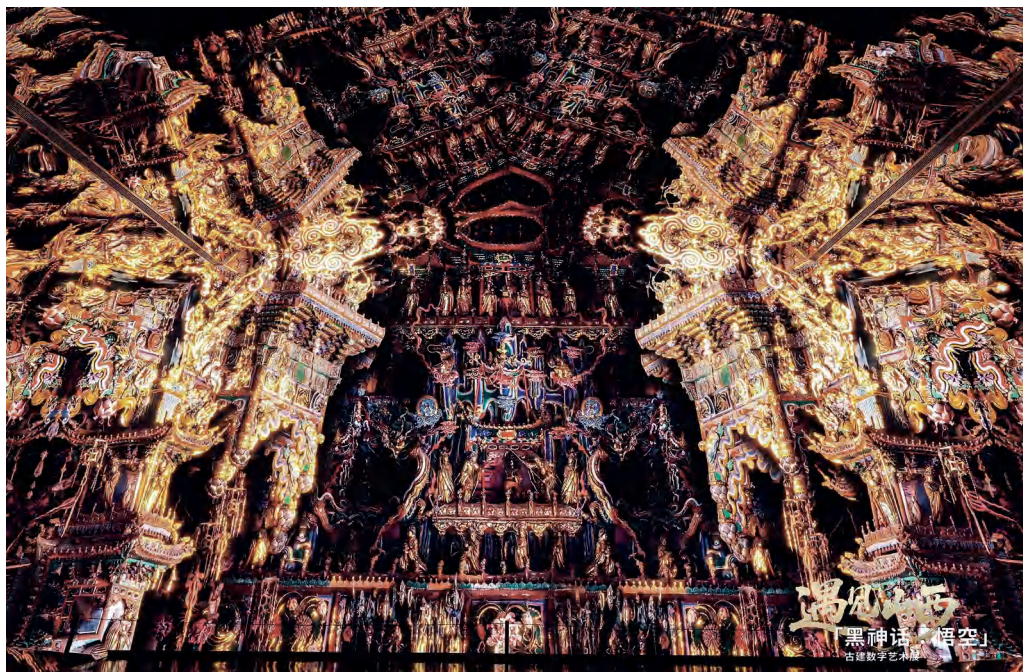
Viewing Difficulties and Communication Bottlenecks of Immovable Cultural Relics

Shanxi is a treasure house of ancient architecture resources in China, with a large stock, complete types and high value. However, a large number of ancient buildings are located in remote areas, with limited carrying capacity and strict management and control. For a long time, the public has faced the viewing difficulties of "cannot enter, cannot understand, cannot see fully".

Traditional ancient architecture display is dominated by graphic display and on-site sightseeing, with single form and strong professionalism, which has weak attraction to young groups and obvious generational communication gap. It is difficult for ancient architecture culture to break through and gain popularity.

At the same time, on-site drainage driven by popular IP causes instantaneous surge of passenger flow, bringing huge pressure to the protection of cultural relics themselves, and the contradiction between protection and opening up is increasingly prominent. Most digital cultural museum exhibitions have the problem of "emphasizing technology over content", with rich visual effects but weak cultural connotation, making it difficult to achieve in-depth transmission of cultural value.

Relying on genuine digital assets and academic materials of ancient architecture, the project adheres to content-oriented and technology-serving principles, realizing the two-way unity of technology empowerment and in-depth content cultivation.



Exhibition Hall

How Game Technology "Replicates" Millennium-Old Ancient Buildings

The project innovatively constructs a four-in-one construction system of "IP authorization-digital



Wukong Figure and Screen

assets-immersive space-interactive experience".

At the bottom layer: relying on genuine authorized materials from Game Science, it integrates high-quality digital resources such as original painting modeling, scene data and animation storyboards to ensure that digital content has both artistic expression and cultural accuracy.

At the middle layer: collaborating with ancient architecture research institutions and academic experts, it completes high-precision digital replication of more than ten precious ancient buildings in Shanxi. It uses light and shadow mapping, naked-eye 3D, digital animation and other technologies to restore the texture, colored painting details and historical features of ancient buildings, and transforms academic research results into visual immersive experience content.

At the application layer: it creates an immersive exhibition area of more than 2,000 square meters, integrates multiple experience forms such as light and shadow shows, spatial audio, large-screen interaction and virtual reality, and builds five themed exhibition areas, forming a complete visiting narrative route from historical background to architectural analysis, from game scenes to cultural connotations.

Following the step-by-step implementation path of "IP co-creation and integration - space construction - full-domain operation", the project steadily completes technical integration, scene creation and regular operation, realizing the in-depth integration of game narrative and ancient architecture culture.

In terms of mode: it breaks the shallow mode of passive drainage at filming locations, and creates a new paradigm of two-way empowerment and in-depth co-creation between game IP and ancient architecture culture, solving the rigid communication problem of ancient architecture with young narrative.

In terms of experience: it pioneers the full-course guide mode of game NPCs, interpreting professional knowledge of ancient architecture such as bucket arches, beam frames and painted sculptures from a popular perspective, greatly lowering the cognitive threshold. It simultaneously displays the behind-the-scenes content of game creation to enrich the cultural connotation of digital cultural museums.

In terms of technology: relying on ultra-long immersive light and shadow performances, it restores the changes of four seasons, day and night alternation and historical overlays of ancient buildings, presenting an artistic narrative effect that cannot be achieved by physical scenes.

The project condenses a replicable path of "top IP authorization and co-creation, lightweight popular science narrative, asset-light exhibition", which can provide a general implementation paradigm for the digital activation of cultural museums nationwide and the in-depth integration of culture and tourism.

Operation Effectiveness and Cultural Communication Value of Immersive Exhibitions

The project is located in Taiyuan Ancient County, successfully creating a new cultural tourism scene of "visiting the city for the exhibition, prospering tourism through culture". It links the government, cultural tourism enterprises, academic institutions and social capital to build a complete industrial chain, promoting regional cultural tourism to upgrade from traditional sightseeing to in-depth cultural experience and digital cultural and creative consumption.

The project popularizes ancient architecture knowledge through interesting interaction and immersive narrative, builds a regular cultural museum popular science system, promotes cross-border cooperation between digital art, game design and cultural museum fields, continuously activates



Twenty-Eight Mansions

regional cultural consumption vitality, and provides an implementable and scalable demonstration model for the activation and utilization of cultural heritage and high-quality development of cultural tourism in the new era.

In terms of protection: it completes high-precision digital archiving and scene replication of multiple remote ancient buildings, precipitates high-quality digital assets, and diverts on-site passenger flow through digital performances, effectively relieving the carrying pressure of cultural relics, and achieving both heritage protection and dynamic communication.

In terms of communication: relying on the global influence of top IP and the all-media matrix, it achieves full-domain breakthrough, accurately attracts a large number of young audiences, and significantly improves the popularity and coverage of Shanxi ancient architecture culture. Immersive experience effectively extends the visiting time, and the communication depth and popular science effect far exceed traditional exhibitions.

Blueprint for Long-Term Operation and National Touring Exhibition

In the future, the project will continue to deepen the integrated track of "games + cultural museums".

On the content side: continuously upgrade the exhibition system based on audience feedback, optimize light and shadow effects and interactive experience, and improve exhibition quality and cultural expression accuracy.

On the industry side: deepen diversified formats such as cultural and creative development, themed activities and academic salons, extend the IP industry chain, and continuously release the empowerment effect of cultural tourism.

On the communication side: steadily promote national touring exhibitions relying on the all-media matrix to expand the radiation scope of the model.

At the same time, a full-dimensional risk prevention and control system will be established. It will strictly standardize the authorization management of IP copyright and ancient architecture digital assets, build a modular content update mechanism, carry out regular community operation, and avoid risks such as content aging, heat decline and copyright infringement.

The project will continue to deepen cross-field collaborative cooperation, polish a standardized and replicable benchmark for digital activation of cultural museums, and lead the innovative inheritance of cultural heritage and high-quality development of the cultural tourism industry in the digital era.



Digital Sharing and Revitalization System for Art Collections

015

Applicant Institution

Zhejiang Art Museum

Led by Zhejiang Art Museum and relying on the advantages of Zhejiang's digital reform, this project builds China's first inter-provincial digital sharing application system for art collections.

Focusing on core demands such as digital governance, cross-domain sharing, inclusive services and activation utilization, the project builds an integrated full-process "Collection Cloud" digital service system, breaks down inter-provincial and inter-museum data barriers, reconstructs collection management and public service modes, and realizes precise management, efficient circulation and universal sharing of art resources. It was selected as one of the Top 10 Cases of Digital Innovation Demonstration in Culture and Tourism in 2024.



The "Data Island" Dilemma in the Art Museum Industry

At present, there are obvious shortcomings in the digital construction of the art museum industry nationwide:

Grassroots art museums have limited collection reserves and insufficient independent exhibition capacity, with cumbersome inter-museum loan queries and inefficient approval processes.

Most venues rely on manual ledger management, with low efficiency in inventory counting, resource statistics and business approval.

Art museums across the country adhere to disparate construction standards and maintain isolated data systems, resulting in persistent data silos. Cross-regional collection sharing, joint curation, and academic exchanges encounter significant obstacles. A large number of high-quality art collections remain stored in warehouses for extended periods, hindering the realization of their public value in aesthetic education and cultural services.

Focusing on the core demands of digital governance, cross-domain sharing, inclusive services and activation utilization, the project builds an integrated full-process service system to promote the equal development of public cultural services.

"Collection Cloud" Breaks Down Regional Barriers

Relying on digital technologies such as cloud computing, big data and artificial intelligence, the project builds a hierarchical and full-closed-loop technical and operation system, forming a new industry service mode of "one network, one platform, cross-terminal, multi-scenario".

The project adopts a mature and stable J2EE architecture and a browser/server (B/S) development model, integrates multidimensional data algorithms, intelligent analysis capabilities, and secure data exchange technologies, and builds a highly compatible and iterative technical support system.

The platform has three core ports:

"Collection Brain" big data platform: unifies digital standards, aggregates collection resources of venues nationwide, realizes online query and inter-museum mutual borrowing, and solves the shortage of grassroots exhibition resources.

"Digital Cockpit": realizes visual monitoring, intelligent research and judgment and precise supervision of collection data, improving the level of industry digital governance.

"Yuecang" mini-program and multi-terminal matrix: builds a large-small screen linkage mode, providing hierarchical and classified precise services for the industry, management departments and the public.

Art Museum Collection Digital Resource Sharing Platform

The project adheres to the parallel development of technical construction and institutional norms, and took the lead in issuing China's first industry standard Specification for Digital Services of Public Art Museums, filling the gap in industry institutions.

Compared with the traditional mode, the project has achieved multi-dimensional innovative breakthroughs:

Technically: builds a full-life cycle digital management system for collections, and intelligently activates sealed art resources.

In mode: breaks regional barriers and pioneers a cross-regional venue collaborative sharing mechanism.

In governance: leads the standardized upgrading of the industry with standardized construction.

In application: covers multiple scenarios of office research, public aesthetic education and cultural and creative development, realizing two-way empowerment of professional governance and inclusive services.

It has formed a mature and replicable paradigm for the digital transformation of art museums.



Art Museum Collection Digital Resource Sharing Platform

Practical Effectiveness of Cross-Domain Sharing and Value of Public Cultural Services

The platform has attracted art museums from multiple provinces across the country to settle in, and collected tens of thousands of collection digital resources, realizing cloud circulation and cross-domain sharing of collection data.

The platform completely replaces traditional manual ledgers, replaces offline warehouse runs with digital circulation, greatly improves the efficiency of collection management, exhibition loan approval, and warehouse-in/out operation and maintenance, reconstructs industry business processes, and promotes the digital transformation of art museums nationwide.

Relying on the shared resources of the platform, dozens of characteristic themed exhibitions have



Digital Cockpit

been launched across the country, and many exhibitions have been rated as national excellent exhibition projects, effectively revitalizing idle collection resources and completely solving the problem of insufficient resources for grassroots exhibitions.

In terms of public services: relying on the multi-terminal matrix, the platform regularly carries out cloud exhibitions, online curation and other services, launches characteristic public education projects such as "Mobile Art Museum" and "Aesthetic Education Villages", expands the coverage of art aesthetic education, and promotes the equalization of urban and rural public cultural services. Many achievements have been rated as national excellent public education projects.

The platform opens compliant digital resources and copyright authorization, empowering cultural and creative development, academic research and aesthetic education, enabling sealed art collections to achieve dynamic inheritance and diversified value transformation, and fully releasing the public service efficiency and contemporary cultural value of high-quality art collections.

Blueprint for Technology Deepening and Ecological Upgrading

In the future, the project will continue to deepen technological iteration, scenario expansion and ecological upgrading, and consolidate its position as a benchmark for the digitalization of art museums nationwide.

Technically: build a dual digital base of "collections + space", promote the construction of venue digital twins, develop AI curation assistants to realize functions such as intelligent exhibition simulation and online curation, and improve the level of smart operation.

In application: develop an AI intelligent Q&A system, build a closed-loop mechanism of audience guidance, opinion collection and service optimization, and comprehensively upgrade the public aesthetic education experience.

At the same time, deepen museum-university cooperation, build university curation workshops, cultivate young art talents, and continuously produce high-quality exhibition results.

The project will continue to expand digital resources, improve industry standards, deepen cross-regional collaborative sharing, cultivate a new digital model of intelligent empowerment and inclusive sharing, continuously release the public value of art collections, and lead the standardized and intelligent high-quality development of the national art museum industry.



"Yuecang" WeChat Mini Program



From "Digital Doubles" to "Wu Dialect Resonance": Non-Legacy Digital Display Practices Driven by AIGC and Dialect Technology

016

Applicant Institution

iFLYTEK (Suzhou) Technology Co., Ltd.

Participating Institution

Suzhou Intangible Cultural Heritage Protection and Management Office & iFLYTEK Input

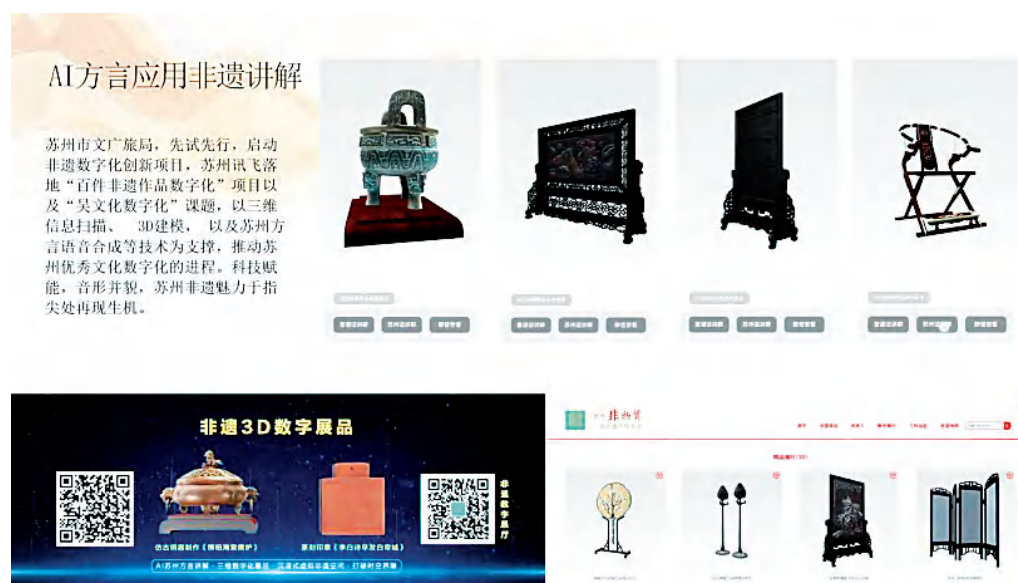
This case focuses on digital technologies such as AIGC, intelligent speech and 3D modeling to empower the digital preservation, innovative display and dynamic communication of Suzhou dialect intangible cultural heritage (ICH). As a living fossil of Middle Chinese, Suzhou Wu dialect carries thousands of years of Jiangnan cultural context and is the core carrier of ICH skills such as Kunqu Opera and Suzhou embroidery.



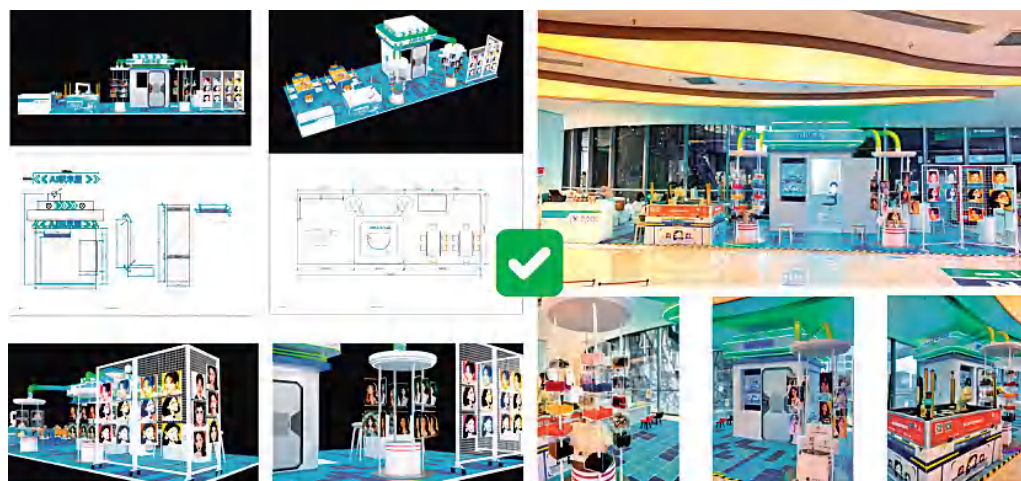
Relying on cutting-edge artificial intelligence technology, the project builds a full-chain digital activation system for ICH, solves the problems of endangered dialects, rigid exhibitions and fragmented digital protection, and creates a new ecology of ICH dynamic inheritance driven by technology, participated by the public and linked by industries.

The "Separation of Sound and Form" Dilemma of ICH Digitalization

At present, dialect inheritance is facing a serious fault crisis. Young groups lack learning channels and their use frequency has dropped sharply. As the core carrier of ICH skills such as Kunqu Opera and Suzhou embroidery, the cultural ecology of Suzhou dialect is continuously shrinking.



Applicant Institution



Display Case Layout

Traditional ICH protection has single static exhibition forms and weak interactivity, making it difficult to convey the unique charm of dialects and ICH skills.

Digital construction generally has the problem of "separation of sound and form": 3D modeling focuses on form preservation, while voice technology focuses on sound effect transmission, with low technical integration, and digital achievements lack vitality.

Traditional oral teaching and manual explanation have limited efficiency, making it difficult to achieve large-scale inclusive communication. Cultural tourism experience, content production and IP consumption are disconnected from each other, failing to form a sustainable activation closed loop.

Relying on iFLYTEK's core technical advantages, the project innovatively constructs an integration framework of "AIGC + AI dialect technology + 3D digital assets + multi-scenario application", creates a software-hardware integrated, full-chain ICH digital solution, and promotes the transformation of ICH from static archiving to dynamic IP operation.

How AIGC Creates "Audible and Speakable" Digital Avatars for ICH

The project integrates four self-developed algorithms to realize 3D face reconstruction, model topology optimization, automatic character fitting and AIGC stylized generation. It pioneers a dual-path content production mode of "3D high-precision scanning + AIGC lightweight generation", which not only ensures high-fidelity restoration of ICH digital assets, but also greatly lowers the threshold for public creation.

The project is implemented steadily in phases:

In 2018: launched special R&D on Suzhou dialect technology, iterating dialect recognition and synthesis models.

In 2023: cooperated with Suzhou Museum to create an AI dialect art exhibition, launching immersive exhibition items such as dialect painting realm, human-machine Kunqu duet, and dialect puzzle teaching, allowing the audience to feel the rhythmic beauty of Wu dialect in interaction.

In 2024: launched the AIGC cultural and creative smart cabin, realizing ultra-fast scanning and fully automatic modeling and output, opening up the closed loop from digital experience to physical cultural and creative consumption. Simultaneously promote ICH digital archiving, public welfare communication and inclusive application.

The project takes the lead in realizing the deep integration of AI dialect speech and 3D modeling, creating "audible and speakable" digital avatars for ICH and solving the long-standing industry problem of separation of sound and form.

It breaks the static archiving thinking and builds a full-chain system of "technology empowerment, human-machine collaboration, public co-creation, and industrial implementation".

It promotes the transformation of audiences from passive viewing to active creation, and narrows the distance between young groups and ICH culture through interesting interaction and customized cultural creativity.

It covers multiple scenarios—including art exhibitions, short-video promotion, inclusive tool design, cultural tourism consumption, and academic research—forming a replicable and scalable new model of culture - technology integration and providing a benchmark paradigm for the nationwide digital activation of dialect-based intangible cultural heritage (ICH).



Interior Design of Exhibition Hall

Dual Effectiveness of Immersive Performances and AIGC Cultural Creativity

In terms of protection: completed high-precision digital preservation of nearly 100 ICH fine works in 26 categories in Suzhou, and built a complete ICH digital asset library. Relying on more than 8 million public welfare interactions to precipitate massive dialect corpus, continuously optimize the AI model and consolidate the foundation of dialect ICH digital protection.

In terms of communication: AI dialect ICH short films have exceeded 71 million exposures across the network, topped local hot searches, and been reported by many official media. The offline AI dialect art exhibition has received more than 400,000 visitors, selected as one of the top ten cases of urban brand communication, effectively breaking the generational barrier of ICH communication and achieving breakthrough communication among young groups.

In terms of industry: AIGC cultural and creative smart cabins have been put into operation in six major cities nationwide, forming a lightweight and replicable new cultural tourism business model. The Suzhou dialect function of iFLYTEK Input Method benefits the public regularly and has become a practical tool for dialect popularization and campus teaching.

The project has won 15 authoritative honors including those from UNESCO. It links cultural museum institutions, universities, art teams and technology enterprises to build a collaborative innovation system, promoting ICH to transform from single exhibition to full-scenario communication, and from public welfare popularization to sustainable industrial empowerment.

Blueprint for Technology Deepening and ICH IP Ecosystem

In the future, the project will continue to deepen technological iteration, IP incubation and scenario expansion.

Technically: deepen the upgrading of dialect AIGC capabilities, develop dialect emotional synthesis and cross-modal content generation functions, open offline applications and standardized interfaces for large models, and optimize digital human interaction experience.

In content: promote the digital archiving of full-domain ICH, create dialect ICH virtual humans, establish a standardized IP authorization mechanism, and promote the integration of ICH digital IP into urban public services.

In industry: upgrade the AIGC cultural and creative incubation system, build an ICH pattern resource library and co-creation platform, open up the whole closed loop of creation, production and sales, and expand cultural tourism application scenarios.

At the same time, three mechanisms of expert review, privacy protection and copyright control will be established to strictly control content quality and data security, steadily promote large-scale replication of the model, continuously polish the benchmark brand of ICH activation through culture-technology integration, and help the innovative development of fine traditional Chinese culture.