Preface

Cultural heritage embodies the ingenuity of human civilization and serves as a foundation for historical and cultural continuity. Preserving, transmitting, and revitalizing these invaluable assets through digital technologies allows them to be vividly presented beyond the limits of time and geography. Such efforts foster a clearer understanding of the diversity and interconnectedness of human civilizations, promoting mutual appreciation, dialogue, and shared prosperity.

As a rising international organization dedicated to the digital domain, the World Internet Conference (WIC) is committed to advancing the innovative application and cross-sector integration of digital technologies. In 2025, the WIC launched a global call for outstanding case studies in digital cultural heritage to systematically document and promote exemplary practices. The initiative received nearly 200 submissions from around the world. Following a rigorous multi-stage review, 40 representative cases from 12 countries and regions were selected. These cases showcase innovative applications of digital technology in cultural heritage conservation, archaeological research, exhibition, and utilization, providing valuable insights for global efforts in digital heritage preservation.

This casebook reflects the achievements already made in digital cultural heritage field while serving as a practical reference for future initiatives. By sharing these experiences, we hope to encourage international exchange and cooperation, and to facilitate the broader adoption of innovative technologies and methodologies in this field.

Looking ahead, the WIC will continue to monitor evolving applications and trends at the intersection of digital technology and cultural heritage. We will further enhance mechanisms for international cooperation and strive to build an open, inclusive, and collaborative digital cultural ecosystem. Together with global partners, we remain dedicated to leveraging digital technologies to safeguard humanity's shared cultural heritage, revitalize ancient civilizations in the digital age, and contribute cultural momentum to the building of a community with a shared future in cyberspace.

World Internet Conference
September 2025

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Cultural Heritage Protection

基于物联网与大数据技术的石窟寺群文化遗产风险综合监测预警平台

Comprehensive Monitoring and Early Warning Platform for Cultural Heritage Risks of Grotto Temples Based on IoT and Big Data Technologies

敦煌研究院 DUNHUANG ACADEMY　　天津大学 Tianjin University　　浙江大学 ZHEJIANG UNIVERSITY　　旗云高科 QWINHI-TECH

01

Comprehensive Risk Monitoring and Early Warning Platform for Grotto Temple Clusters Based on IoT and Big Data Technology

▶ **Applicant Institution**

Dunhuang Academy

▶ **Participating Institution**

Tianjin University;
Zhejiang University;
Wuhan Qiyun High-Tech Engineering Technology Co., Ltd.

This case innovatively establishes a two-tiered risk monitoring and early warning system for grotto temple clusters. By integrating IoT and big data technologies, it addresses the challenge of weak monitoring capabilities for small and medium-sized grottoes. Its core value lies in: 1) Pioneering a tiered management model: The regional platform provides standardized monitoring services (e.g., disaster warning, data analysis), allowing small and medium-sized grottoes to be connected by simply deploying equipment, significantly reducing construction and operational costs. 2) Integrating diverse technical means: It tackles technical pain points like heterogeneous sensor access and massive data management, enabling real-time risk monitoring and closed-loop handling. 3) Collaborating with professional agencies (e.g., meteorology, seismology) to provide customized disaster warnings. This enhances the overall disaster prevention capacity for regional grotto clusters and supports the systematic protection of immovable cultural relics.

➲ Monitoring Needs and Challenges in Grotto Temple Protection

Grotto temples, as significant cultural heritage sites, are inherently vulnerable to meteorological events, geological hazards, and human activities due to their cliff-carved nature, facing risks like structural instability, weathering, and water seepage. Currently, most small and medium-sized grottoes suffer from weak protection management due to funding, personnel, and technological constraints: they lack standardized condition assessment systems and robust risk monitoring mechanisms, making it difficult to identify real-time hazard and intervene. Furthermore, the need for specialized monitoring of natural disasters starkly contrasts with the undercapacity of these smaller grotto sites, calling for integrated technological solutions to create efficient, inclusive monitoring that enables a shift from passive rescue to active prevention.
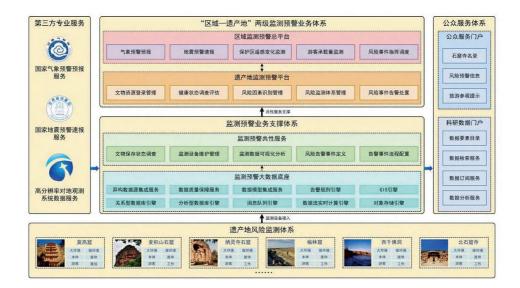
➲ Building a Tiered Monitoring Technical System

This case relies on a two-tier architecture to create a technical system covering monitoring, analysis, warning, and response.

Two-Tier Operational System: The regional monitoring platform consolidates common services (e.g., disaster warning, data management), providing standardized tool modules for small and medium-sized grottoes. Heritage sites only need to deploy targeted monitoring equipment (e.g., temperature/humidity sensors, structural monitors) to connect to the regional platform, achieving real-time risk perception.

Technical Support System: Based on a big database, it solves challenges like heterogeneous sensor access, high-concurrency data storage, and historical data retrieval. It collaborates with professional agencies (meteorology, seismology, etc.) to provide customized disaster warnings (e.g., rapid reports on heavy rains and earthquake), expanding monitoring coverage and accuracy.

Service Extension: Provides information like grotto directories and tourism tips to the public, and offers data retrieval and analysis tools to researchers, achieving synergy between protection and utilization.

Implementation Path from Pilot to Expansion

This case has been implemented in several phases to gradually expand monitoring coverage.

Phase I Pilot (Completed): Took 6 grotto sites under the care of Dunhuang Academy (Mogao Caves, Maijishan e.g.) as targeted objects, to build a two-tier "Provincial Monitoring Center–Heritage Site" system. It achieved dynamic condition assessment, combined disaster warning, and realized closed-loop handling of risk events, validating the feasibility of the tiered model.

Demonstration Site Innovation: Designed lightweight monitoring solutions for small/medium grottoes with shortage of power and network coverage (e.g., Yulin Lower Cave Grotto), providing a practical access model for remote areas.

Phase II Planning: Aims to cover 236 grotto sites in Gansu Province, improve risk assessment mechanisms, expand disaster warning channels, enhance intelligent data analysis capabilities, and form a unified provincial monitoring network.

➡ Innovative Breakthroughs in Technology and Model

This case achieves dual breakthroughs in operational model application and technological application.

Model Innovation: Cloud-edge architecture lowers the entry barrier for small/medium grottoes. The regional platform centrally provides professional services (e.g., data analysis, equipment maintenance), avoiding low-level redundant construction. Collaboration with professional agencies enables coordinated monitoring, filling the capability gap in disaster warning for small grottoes.

Technological Breakthrough: A management platform tailored for cultural relic monitoring was built using big data technology, solving issues like complex heterogeneous device access and low data storage efficiency. Standardized module design enables full-process automation from risk identification to alert and handling, improving response time.

➡ Practical Results and Demonstrated Value

This case has achieved multi-dimensional results.

Protection Efficacy: The six sites covered in Phase I have established comprehensive monitoring systems, enabling real-time warnings and closed-loop handling, promoting preventive conservation. Standardized assessment tools support decision-making for precise treatment of deterioration.

Economic Benefits: The shared services via the regional platform reduce redundant construction costs for small/medium grottoes, improving the efficiency of conservation funding. It lowers labor costs and avoids high restoration expenses caused by delayed intervention. Improved protection status, and boosts tourism economic development.
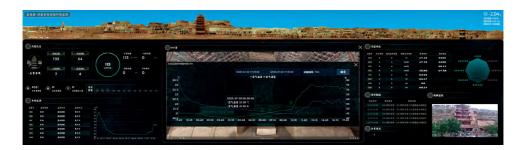
Social Benefits: Promotes the transition of small/medium grottoes from passive protection to active prevention, elevating the level of technological conservation. It provides a scientific basis for open management of grottoes, enhances public cultural confidence, and forms a virtuous cycle of protection and utilization.

➲ Future Expansion and Planning

Technological Upgrade: Introduce AI technology to analyze massive monitoring data, build correlation models for risk factors, enhance predictive capability for deterioration and health assessment, and strengthen intelligent decision support.

Scenario Extension: The Phase II project covers 236 grottoes across Gansu province. Subsequent expansion will include other cultural heritage types like the Great Wall and ancient buildings. The tiered monitoring model will gradually be promoted across Northwest China and beyond.

Support Mechanism: Seek special funding and social capital support. Rely on the expertise of the Dunhuang Academy National Outstanding Engineer Team to ensure technological iteration. Deepen international cooperation (e.g., with the Getty Conservation Institute, USA) to introduce advanced experience.

探元计划

2024

探寻科技助力
中华文化焕活的创新范式

指导单位　国家文物局科技教育司

发起单位　中国文物信息咨询中心／国家文物局数据中心　腾讯SSV｜数字文化　腾讯研究院 Tencent Research Institute　CASVI 社会价值投资联盟

支持平台　腾讯SSV探元

02

Tanyuan Plan 2024 – Cultivating Demonstrations of Digital Technology Collaborative Innovation Applications in the Cultural Heritage Sector

▶ ## Applicant Institution

China Cultural Heritage Information and Consulting Center (Data Center of National Cultural Heritage Administration)

▶ ## Participating Institution

Tencent SSV Digital Culture Lab
Tencent Research Institute
China Alliance of Social Value Investment (Shenzhen)

The Tanyuan Plan 2024, guided by the Science, Technology, and Education Department of China's National Cultural Heritage Administration, was jointly initiated by the China Cultural Heritage Information Center (NCHA Data Center), Tencent SSV Digital Culture Laboratory, Tencent Research Institute, and the Social Value Investment Alliance (Shenzhen). To address common industry challenges, the Tanyuan Plan 2024 Scenario Co-creation Project selected specific scenarios to explore digital technology innovation, implement innovative technological applications within specific cultural and museum contexts, and promote the transformation of co-created outcomes. Through an innovative funding and incubation model for culture and technology, it provides comprehensive support via three pathways, leveraging digital technology to break traditional limitations, revitalize Chinese culture, and achieve efficient protection, standardized development, and popular publicity of cultural heritage.

➲ Diverse Integration, Innovation Leadership
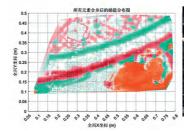
In digital recording and preservation scenarios, technologies like high-precision 3D laser scanning and temporal optical twinning are used. In artifact restoration and digital research scenarios, artificial intelligence and large language models are applied. In virtual display and publicity scenarios, there is a deep integration of multi-modal knowledge like AI large models with spatiotemporal interactive experiences, and AI-driven image-text retrieval and creation; historical, linguistic, and spatial aspects of cultural scenes are introduced into immersive experiences through AI-powered story games and 3D time-travel forms. In interdisciplinary crossover and multiple scenarios, with focus on typical pain points like prevention, protection, research, management, and utilization, multiple disciplines (biology, chemistry, materials science, nuclear physics, aerospace science) are brought together to make breakthroughs and applications of key technologies.

➲ Solving Industry Pain Points, Leveraging precise and Efficient Scenario Application

Achieved technological breakthroughs on core issues in five major scenarios:

Kizil Grottoes, Xinjiang: Leveraged Terahertz Time-Domain Spectroscopy (THz-TDS) for non-destructive testing and image recognition of smoke-obscured

所有元素合并后的插值分布图

murals. Based on an AI-powered framework for mural virtual restoration, a dual-model-driven chain-of-thought strategy was employed to accurately restore damaged murals based on professional knowledge, achieving preservation and development of cultural heritage.

Hunan Museum: Leveraged AI technology to achieve millimeter-level precision restoration of Mawangdui silk artifacts. Through multi-modal artifact data training, patterns matching the style and decorative features of the silk textiles were intelligently generated.

Longmen Grottoes: Achieved high-precision 3D modeling of shallow relief surfaces through deep-learning-based photometric stereo technology. Adopted multi-modal data alignment methods for automatic detection, classification, cataloging, and rapid retrieval of decorative patterns. Enhanced the protection and utilization level of the grottoes, significantly reducing equipment costs and improving data acquisition efficiency.

Jingdezhen Ceramic Institute: Utilized self-developed temporal domain technology to provide ultra-high precision digitization and optical twinning solutions for the Jingdezhen co-creation project, building a digital asset repository of ceramic cultural heritage, achieving digital presentation of true optical images and micron-level texture details of ceramic works. Meanwhile, through brick-and-mortar thematic venues and the online app "Thousand

Museums & Ten Thousand Porcelains", it enables visitors to play the role of "digital guardians" for ceramic preservation, showcasing the unique value and charm of Jingdezhen's ceramic cultural heritage to the world.

Hong Kong Joint Publishing Group: Through deep integration of digital publishing and cultural heritage, it leveraged digitized ancient texts to restore the historical culture of Kowloon Walled City, constructing a 3D virtual space to recreate Chinese cultural context. High-precision digitization transformed historical books related to Kowloon Walled City into virtual reality experiences, allowing users to have an immersive experience of its historical and cultural charm.

➲ Practical Outcomes

Expanded Scale and Coverage: It collected 279 projects, selected 27 technical solutions, and promoted the implementation of 6 key scenarios. It boasts multiple dimensions technologies, large-scale participations, forming a leading open technology and outcomes.

Significant Results in Digital Preservation: It promoted and validated outcomes in five major scenarios: completed digital mural restoration, achieved millimeter-level silk artifact restoration with greatly improved efficiency, reduced modeling equipment costs, solved ceramic acquisition challenges, and created interactive experiences.

Accelerated Industry Chain Collaboration and Ecological Development: Upgraded projects through a tripartite mechanism, with some outcomes deeply integrated into the business of scenario partners.

Combination of Research & Education and Resource Platform Building: It funded university labs, promoted traditional culture as teachable, usable and creatable, formed practical closed-loops of protection and dissemination, and yielded economic, social, and educational research benefits.

Future efforts will be made to deepen AI application in cultural heritage and intangible cultural heritage digitization, and improve image recognition restoration accuracy and cultural connotation interpretation; to explore higher precision and more efficient 3D modeling technologies; to promote interdisciplinary integration of emerging technologies like Terahertz and Muon imaging with digital technology; and to further establish cooperation with relevant foreign institutions and enterprises for technical exchange and collaborative projects.

03

▶ **Applicant Institution**

Northwest University

▶ **Participating Institution**

Emperor Qinshihuang's Mausoleum Site Museum

AI-Based Digitalization and Virtual Restoration Technology Case for the Terracotta Army

This case focuses on the Terracotta Army, innovatively constructing an AI-driven digital restoration system for damaged artifacts. Through breakthroughs in high-precision 3D modeling, intelligent fragment matching, and virtual-physical dual-track restoration, it addresses the pain points of traditional manual restoration: low efficiency, high error rates, and reliance on experience. Its core value lies in: 1) Establishing a technical framework workflow of precise modeling, intelligent matching and immersive display, achieving sub-millimeter 3D scanning and intelligent reassembly, multiplying restoration efficiency. 2) Pioneering virtual restoration precursor and physical restoration validation models, providing precise plans for physical restoration while enabling digital substitutive preservation for severely damaged artifacts. 3) Forming a replicable artifact restoration methodology already applied to various artifacts like pottery figures and bronze ware, driving the industry's transition from experience-driven to data-algorithm-driven collaboration.

➔ Digital Transformation Needs for Damaged Artifact Restoration

Most of the unearthed Terracotta Warriors are in dilapidated and damaged conditions due to natural and human disruption, with less than one-eighth of over 8,000 artifacts restored. Traditional restoration for these massive fragments relies on experience, with challenges like long cycles, erroneous reassembly, and potential secondary damage. To achieve long-term preservation, scientific reconstruction, activation and utilization, digital technology is needed to break bottlenecks – requiring precise 3D recording of artifact information, efficient fragment matching and original form restoration, plus innovative display methods for public appreciation. This case builds an AI-driven digital restoration platform focusing on three core issues: high-precision 3D modeling, intelligent matching/restoration, and immersive interactive display.

➔ Digital Restoration Technical Framework

This case created an integrated technical system including modeling, matching and display, achieving a closed loop from data acquisition to value dissemination.

High-Precision 3D Modeling: Self-developed third-generation structured light scanning devices integrate dual robotic arms, HD cameras, etc., achieving sub-millimeter (0.05mm precision) 3D data acquisition within minutes without contact, simultaneously capturing surface texture information and providing a precise digital base for restoration.
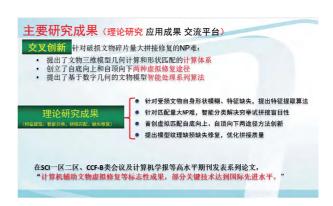
Intelligent Fragment Matching & Virtual Restoration: Built a multi-feature fusion geometric computation system. Intelligent classification algorithms narrow candidate fragment sets,

combined with bottom-up and top-down paths for precise matching. A restorer interactive feedback mechanism optimizes virtual restoration plans, supporting prediction of original damaged parts and filling of missing sections.

Immersive Display & Interaction: Combined VR/AR technology to create immersive experience systems. The public can virtually observe the entire restoration process, even participate in virtual reassembly, shifting from passive viewing to active participation.

➡ Phased Implementation Path

This case launched in 2018, implemented in four stages.

Data Acquisition & Model Building (2018-2019): Completed the third excavation of Pit 1 and 3D scanning and modeling of fragments from Pit 9901 of the Terracotta Warriors. Developed feature extraction systems. Published 62 SCI/EI papers, and applied for 25 invention patents.

Core Algorithm Development (2020-2021): Proposed a dual-path restoration strategy of fragment recognition and template guidance, optimized the methods for restoring irregular holes and curved surface textures, and improved automatic restoration performance.

Engineering Application (2020): Completed virtual restoration of over a hundred pottery figures and horses at the Qinshihuang Mausoleum Museum. The virtual restoration plan for the "Studded Warrior Figure" put errors within 1mm, validating the feasibility of the manual restoration under virtual guidance.

Accomplishments Promotion (2022-Present): Promoted the transfer of two invention patents and established two enterprise standards. Built a smart museum cloud platform, integrating resources from seven institutions. Technological achievements were widely reported by media like CCTV and BBC.

➡ Dual Innovative Breakthroughs in Technology and Models

This case achieves multiple innovations in technology and industry models.

Technological Breakthroughs: Intelligent reassembly algorithms enables the process of hundreds of fragments simultaneously, solving the "fragment scatter" problem, and increasing restoration efficiency several times compared to manual work. Multi-feature fusion models accurately handle blurry and incomplete fragments, expanding applicability to various damaged artifacts. Naked-eye 3D interactive displays improve information transmission efficiency by threefold compared to traditional display cases.

Model Innovation: Made the first "dual-track restoration" model to carry on virtual and physical restoration at the same time, achieving digital "substitutive preservation" for severely damaged artifacts (e.g. the Right Outer Horse). Built a collaboration network with universities,

虚拟复原作用1：指导实体复原

泡钉俑虚拟复原方案　　指导实体复原拼接

虚拟复原作用2：可替代实体复原

C2-4 号右骖马复原指导手册
西北大学可视化研究所

右骖马虚拟复原方案

右骖马虚拟复原模型

museums and enterprises, forming a closed loop including basic research,engineering applications and market transformation, accelerating technology implementation.

➔ From Restoration Innovation to Cultural Communication

This case has achieved significant results across multiple dimensions.

Reform of Restoration Industry: Promoted the development of artifact restoration from experience-based to AI-guided, complete virtual restoration of over a hundred Terracotta Warriors, verified the reliability of the pioneering model of "virtual restoration", driving industry upgrades.

Cultural Communication Expansion: Built a multi-level communication system through the smart museum cloud platform, naked-eye 3D displays, etc. Related achievements were broadcasted by over 200 global TV stations, reaching over 80 million people, enhancing the international influence of Chinese civilization.

Industrial & Educational Value: Core technology is leveraged to make products like digital modeling equipment and display systems that are successfully deployed in multiple cultural heritage institutions. Established a composite talent training system, published Chinese and English monographs, conducted popular science activities for youth groups.

➲ Technological Iteration and Application Expansion

This case will advance sustainable development from multiple dimensions.

Technological Innovation: Optimize fragment recognition algorithms, incorporate historical semantic knowledge graphs to aid restoration. Enhance AR/VR interactive functions, support multi-person collaboration and restoration process replay.

Application Expansion: Complete digital restoration of unrepaired sections of Pit 1 by 2025. Expand the use of the technology to other artifact types like bronze ware and murals, extend services to small/medium cultural heritage institutions.

Resource Support & International Collaboration: Seek special funding support, improve technical standards. Promote joint projects with countries participated in the Belt and Road Initiative, take part in international cultural preservation standard-setting, enhance the influence of the "China's Solution."

龙门石窟

微痕浅浮雕三维建模及纹饰图案的自动理解与建库检索

04

3D Modeling of Micro-Trace Reliefs and Automatic Understanding, Cataloging, and Retrieval of Decorative Patterns at Longmen Grottoes

▶ **Applicant Institution**

Longmen Grottoes Academy

▶ **Participating Institution**

Wuhan University; China Alliance of Social Value Investment (CASVI)

This case innovatively constructs a digital protection system for grotto cultural heritage, combining high-precision modeling, intelligent understanding and structured cataloging. Addressing the challenge of protecting Longmen's micro-trace reliefs (etching depth < 0.05mm), it achieves three breakthroughs: 1) Uses refined photometric stereo technology to achieve sub-millimeter 3D modeling in cramped, unevenly lit grotto environments, balancing precision and environmental adaptability. 2) Introduces pre-trained visual large models and combines manual assistance to achieve automatic extraction and classification of decorative patterns, breaking the limitation of traditional manual tracing. 3) Builds the first Longmen Grottoes decorative pattern database supporting multi-modal retrieval, connecting data acquisition, modeling, understanding and application, and providing a replicable technical model for the digital protection, activation and utilization of grotto-type cultural heritage.

➲ Technical Needs and Challenges in Micro-Trace Relief Digitization

Longmen Grottoes, a treasure trove of multi-civilization stone carving art, carries rich historical and artistic value in its micro-trace reliefs and complex patterns. However, digital protection faces multiple technical adaptation needs: Shallow relief etchings are subtle (most of its depth <0.05mm) and traditional methods like laser scanning and photogrammetry cannot achieve modeling precision and efficiency in cramped, unevenly lit spaces. Patterns are diverse and complex, so relying merely on manual tracing is difficult to make systematic management and digital archiving Existing computer vision methods suffer from weak generalization and low recognition accuracy. Therefore, innovative technical solutions are needed to meet both high-precision modeling demands and enable intelligent parsing and efficient utilization of pattern information.

➲ Building a Digital Technology Framework

This case builds an integrated technical system around modeling, recognition and cataloging to precisely solve the digitalization challenges of micro-trace reliefs.

Sub-Millimeter 3D Modeling: Uses refined photometric stereo technology. A "fixed viewpoint – varying light source" mode captures image sequences, generating normal maps, depth maps, and 3D point clouds. With just portable cameras and LED lights, it enables non-contact modeling with errors controlled within 0.1mm, adapting to complex grotto environments.

Intelligent Pattern Extraction & Classification: Based on pre-trained visual large models, parameters are optimized through fine-tuning with a few samples, assisted by manual review to generate continuous line drawings. Achieves automatic extraction and classification of over 30 types of patterns (Buddhist motifs, plants, animals, etc.), balancing efficiency and accuracy.

Structured Database Construction: Employ indices like cave, historical period and pattern type to establish a pattern database encompassing images, semantics, and 3D information. Support multi-modal retrieval (image similarity, keywords, category), enabling rapid positioning and comparison of patterns within 3D models.

➲ Phased Implementation Path and Innovative Breakthroughs

This case advanced technology implementation in three stages, achieving a closed loop from trial to application.

Data Acquisition & Modeling Trial Stage: Selected typical caves like Weizi Cave and Lotus Flower Cave to verify the feasibility of refined photometric stereo technology, successfully building sub-millimeter 3D models, solving the precision insufficiency of traditional techniques in complex environments.

Pattern Recognition & Processing Stage: Based on modeling data, it combined visual large models to complete automatic pattern extraction, and establish annotated datasets and structured line drawings with assistance of manual review, breaking the bottleneck of reliance on manual labor for pattern parsing.

Database Construction & Function Expansion Stage: Developed multi-modal retrieval functions, achieving systematic management and rapid utilization of pattern data, connecting the chain of data, information and application.

Innovative breakthroughs include: First application of photometric stereo technology for sub-millimeter modeling in a grotto setting; Established a point cloud adjustment mechanism integrating 3D etching and multi-feature fusion, improving overall model consistency; Built the first Longmen Grottoes pattern database, achieving full-process integration from pattern recognition to retrieval.

➡ Practical Results and Application Value

This case has achieved significant results in technical, academic, and collaborative dimensions.

Technical Efficacy: Modeling efficiency improved by over 50% compared to traditional articulated arm laser scanning, and errors stabilized below 0.1mm, significantly enhancing the precision and feasibility of micro-trace relief digitization.
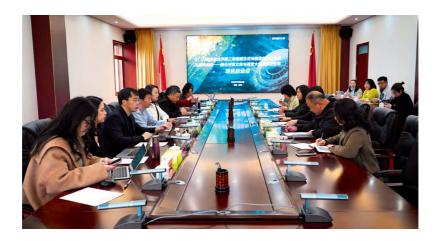
Academic Value: Organized and archived about 600 pattern drawings covering over 30 types, providing systematic digital materials for research in archaeology, art history, etc.

Collaborative & Talent Value: Built a collaboration mechanism including cultural institutions, universities and enterprises which trained over 30 interdisciplinary young talents, forming a talent system linking research and protection.

➲ Future Application Expansion and Sustainable Planning

This case will continue to deepen technological iteration and scenario application.

Technological Upgrade: Optimize 3D reconstruction algorithms for more complex scenes, enhance the semantic recognition capability of visual large models for patterns, build cross-scenario pattern knowledge graphs.

Application Scenario Expansion: Implement in areas like research monitoring (weathering rate analysis, restoration assessment), educational display (VR study tours, holographic interaction), cultural creative transformation (empowering intangible cultural heritage crafts, digital collection development), promoting the integration of culture, technology and industry.

Resource Support & Risk Response: Seek special funding and social capital support, consolidate talent tier. Establish technical backup plans to counter equipment iteration risks, protect data security and prevent copyright issues through permission management and digital watermarking.

文化遗产的数字化 "基因库"

浙 江 大 学 高 保 真 采 集 、 智 能 处 理 与 活 化 应 用 体 系

05

Digital "Gene Bank" for Cultural Heritage: Zhejiang University's High-Fidelity Acquisition, Intelligent Processing, and Activation Application System

▶ ### Applicant Institution

Cultural heritage institute Zhejiang university

▶ ### Participating Institution

Dunhuang Academy;
Yungang Research Institute;
Longmen Grottoes Research Institute, etc.

This case innovatively constructs a cultural heritage digital "Gene Bank" system, achieving three breakthroughs: 1) Overcoming the challenge of adapting to diverse cultural relics, integrating multi-source data acquisition technologies (laser scanning, photogrammetry, etc.), developing non-contact, adaptive equipment to balance micron-level high precision with large-scale acquisition. 2) Establishing a technical framework of collection, processing and activation, using AI intelligent processing (deterioration identification, virtual restoration) and lightweight modeling to solve bottlenecks in complex structure reconstruction and massive data application. 3) Creating a high-quality standard system and a "separation of three rights" operational model, promoting cross-domain sharing of digital resources (academic research, exhibition, cultural creativity), achieving a value leap for cultural heritage from digital archiving to "living utilization."

➲ Technical Adaptation and Needs in Cultural Heritage Digitization

Cultural heritage digitization needs to address multi-dimensional challenges, which also drive technological innovation needs.

Acquisition Level: Diverse artifact types (immovable grottoes, ancient buildings; movable bronze ware, paintings/calligraphy) face issues like large volume, complex environments (poor light, narrow spaces), fragility. Image acquisition technologies adaptable to different scenarios are needed. Balancing efficiency between high precision (micron-level) and large-scale image acquisition, and lack of data format standardization requires systematic solutions.

Processing & Application Level: Insufficient precision in 3D modeling of complex structures (hollowed, curved surfaces); immature AI application in deterioration detection and automatic restoration; digital resources are difficult to display online due to large file sizes; barriers that prevent interdisciplinary collaboration; unequal emphasis between intellectual property and data security.

Management Level: Uneven distribution of funding and technical resources; shortage of composite talent; lack of long-term maintenance mechanisms; demands for unified standards and sustainable operational models.

Based on the above-mentioned issues, this case focuses on "high-fidelity image acquisition, intelligent processing, activation application", building a digitization system covering the entire process, responding to the core needs of permanent preservation and living transmission of cultural heritage.

➲ Technical System of the Digital Gene Bank

This case builds an integrated technical framework including acquisition, processing and display, achieving precise capture and efficient utilization of cultural heritage digital resources.

Multi-Source Acquisition Technology: Integrates laser scanning, photogrammetry, multi-spectral imaging, etc., with supporting lightweight equipment (drones, handheld scanners) and adaptive environmental control (smart lighting, temperature/humidity monitoring) to ensure non-contact, full-element coverage with micron-level precision. For large cultural relics like grottoes and ancient buildings, it develops specific scanning robots to adapt to extreme environments; for movable cultural relics, it develops high-resolution imaging systems to capture pattern and color details.

Intelligent Processing System: Achieves data pre-processing through point cloud denoising, multi-source data registration; uses NeRF neural rendering, Gaussian splatting for 3D modeling; introduces AI algorithms (deterioration identification, age determination, knowledge graphs) to enhance automated processing capability, e.g., using GAN networks to restore incomplete patterns, building digital restoration expert systems.

Activation Display Application: Relies on lightweight engines (WebGL, UE5 Nanite) for efficient display of high-precision models; develops interactive scenarios like VR archaeology, AR guided tours, metaverse exhibition halls; uses digital twin technology for dynamic monitoring of artifact status, supporting academic research and public education.

➡ Practical Path from Technological Innovation to Value Transformation

This case promotes the implementation and transformation of technological outcomes through standardization, cross-domain application, and model innovation.

Standard & Resource Library Construction: Took the lead in the compilation of 8 industry and local standards (e.g., *3D Digitization Acquisition and Processing for Movable Cultural Relics*). Established a 500TB-level digital resource library, covering over 220 key cultural relics across 25 provinces/municipalities (including 7 World Heritage grotto sites, ancient buildings).

Typical Case Practice: Completed high-precision 3D printing replication of Cave 3 and Cave 12 at Yungang Grottoes, costing only 1/5 the price of traditional methods. Promoted digital archaeological surveys of Xumishan Grottoes, Leiyin Cave, etc., publishing the first digital archaeological report. Held digital exhibitions like "Compiling Classics in a Flourishing Era," with visitors exceeding 500,000 on one website.

Innovative Operational Model: Adopts a model whereby ownership belongs to the State, usage rights belong to the operator and profits feed back into the protection fund. The touring exhibitions on replica cave generated 3 million yuan in annual ticket revenue, brought in over 5 million yuan of annual output for cultural creativity and related industries, and created over 200 new jobs.

➡ Future Expansion and Sustainable Planning

This case includes three aspects: technological improvements, industrial expansion, and international cooperation.

Core Technology R&D: Focus on breakthroughs in intelligent acquisition technologies like 0.01mm-level structured light scanning, multi-spectral imaging (8 bands), grotto scanning robots. Upgrade AI applications (material aging prediction, virtual restoration training systems), build cross-spacetime exhibition platforms.

Industry & Education Integration: Promote technology application rate in the cultural heritage industry to over 80%, support digital cultural creativity development, create economic value exceeding 100 million RMB. Establish talent training systems, form interdisciplinary teams (computer science, archaeology, art history, etc.), cultivate composite talent.

Long-Term Planning: Invest funds in equipment R&D, talent training, and international projects from 2024-2030. Build a nationally unified standard digital resource library. Promote technology export and international cultural exchange, making the digital "Gene Bank" a "Digital Ark" for civilization continuity.

06

"Liangzhu 5000+" Intelligent Digital/AI-Powered Application

▶ **Applicant Institution**

Hangzhou Archaeological Ruins of Liangzhu City World Heritage Monitoring and Management Center

▶ **Participating Institution**

Hangzhou Yuhang Big Data Operation Co., Ltd.

The Liangzhu Archaeological Site, a significant late Neolithic period site inscribed on *the World Heritage List* in 2019, is the focus of this case study on the Liangzhu 5000+ Intelligent Digital/AI-Powered application. It aims to address common challenges in cultural heritage preservation through digital technology, promoting the sustainable protection of Liangzhu. The field faces issues like isolated monitoring data, fragmented technology application, and poor adaptation of new technologies to specific scenarios. The Liangzhu 5000+ application was launched in April 2022, covering four major scenarios: spatial governance, grid-based smart management, value research, and "cultural relics +". This case primarily involves the first two scenarios and eight sub-scenarios, exploring paths to leverage digital technology to reshape workflows, enhance protection effectiveness, and improve the adaptation of technology into scenario.
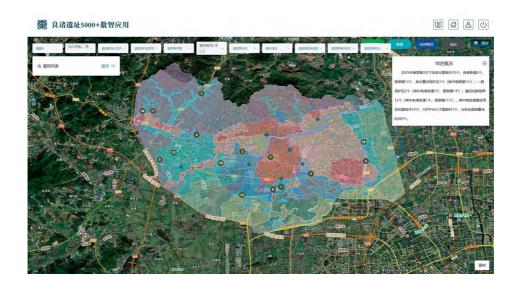
➲ Cross-Department Data Integration for End-to-End Workflows

This case uses data integration as the foundation for business collaboration, combining over 30 million data from nine departments including Planning and Natural Resources, Agriculture, and Rural Affairs. It establishes a differentiated user role system, enabling data to be collected for shared usage, breaking down data barriers and information asymmetry between departments. For construction project management within the Liangzhu protected area, the case integrates Liangzhu spatial information with provincial spatial data on a unified map, collaborates with approving departments to implement spatial control requirements, transforms cultural relic pre-approval from passive to proactive service, builds a full-process project management system, enables reporting and handling of anomalies with one click, and forms a cross-departmental closed loop.

➲ AI-driven Parcel Verification Enhances Management Efficiency

Addressing the parcel verification tasks through satellite remote sensing issued periodically by the Zhejiang Provincial Cultural Heritage Bureau, this case builds upon the existing verification interface to add functions like AI analysis, three-color status management, advanced search, and automatic analysis export. The parcels received after mapping are compared via AI analysis with the existing construction project database to pinpoint suspected unauthorized projects. Three-color management allows real-time tracking of verification progress, enables advanced search in accordance with area of protection or area under jurisdiction, and automatically generates summary reports. This model significantly saves labor costs and strengthens prevention on cultural relic violations.

➔ Twin Approaches of Sensors & Digital Address Natural Risks

This case addresses natural influencing factors by combining digital technology with conservation research. Fifty-five sensors (e.g., environmental temperature/humidity, groundwater level) were installed at the Laohuling and South City Wall sites. Tilted aerial photography created 3D models of the overall environment, protective shelters, and archaeological profiles, building a digital twin scenario. For the Laohuling site, which uses closed-environment high-humidity display, the twin model monitors soil moisture and temperature in real-time to ensure stability. For the semi-enclosed South City Wall site which is susceptible to typhoons and rain, a flooding analysis model simulates extreme weather, identifies weak points with surrounding water flow, and enables targeted emergency plans, shifting from passive response to active warning.

➔ Drones and AI Recognition Prevent and Control Human Risks

Facing a vast protected area (161.59 km^2) with 316 site points, 85 heritage elements, and less than 10 percent enclosed area, this case uses AI algorithms and monitoring equipment. Five automated drone airports were built; drones regularly execute 5 patrol routes for full coverage. Video streaming from drones and 1006 cameras within the area are accessed via 32-channel patrol to 4 superbrain servers. AI models for intrusion detection, construction vehicle recognition, and building material recognition are deployed. Using AutoML for automatic algorithm training, cloud inference, and model iteration, videos are intelligently analyzed to identify looting, unauthorized digging, and construction risks, capture real-time images, issue automatic warnings, and dispatch tasks instantly to relevant personnel. This overcomes

traditional manual monitoring's shortcomings (incomplete coverage, untimely discovery, delayed response), achieving all-weather, multi-dimensional protection for key sites.

➡ Pioneering Supervision Grid Strengthens Protection and Warning

This case classified 124 cultural relic grids and 686 inspection points, coordinating inspection teams and local grid members. To date, over 367,000 inspections have been completed, covering 3.468 million km of patrol trajectory, and a cultural relic safety supervision mechanism has been established featuring government leadership, departmental coordination, social

participation, and joint management. Since launch, it has effectively handled 186 warning events with over 95% accuracy, successfully forming a management and responsibility closed loop process.

Forming a Replicable System, Gaining Wide Recognition

The application covers the entire life-cycle from excavation to utilization. Sub-scenarios support each other; business and technology R&D promote each other. Ten sets of cultural relic safety application components (e.g., intrusion detection, vehicle recognition) were refined, adaptable to various site changes. Components like parcel verification, task dispatch, and IoT device access have been reused in monitoring systems for the Grand Canal (Jiaxing and Nanxun sections). Nine software copyrights were approved, forming a practical, replicable smart governance system. This case has won awards like the National Excellent Case for Archaeological Site Protection and Display and the Third Digital Heritage Best Practice Case, providing a high-quality example for digital-intelligent cultural heritage protection.

Future work will focus on three areas:

1) Iterating the application and building a demand-driven supply chain, to enhance spatial and grid management, deepen value research and "cultural relic+" scenarios, optimize AI algorithms, integrate new technologies, and promote sustainable site development.

2) Fostering mutual empowerment between monitoring and research: establishing data standards, strengthening data quality control, conducting multidisciplinary research based on the Southern Humid Environment Earthen Site Protection Lab, analyzing data to advance protection through detecting changes and identifying risks.

3) Refining and promoting experience: continuously refining components, applying for copyrights, promoting domestic adoption via "standard + component + training", sharing experience internationally, providing technical pathways for global cultural heritage protection.

07

Great Wall Heritage Value Mining and Multi-Scenario Interpretation Solution Based on Digital Intelligence Technology

▶ **Applicant Institution**
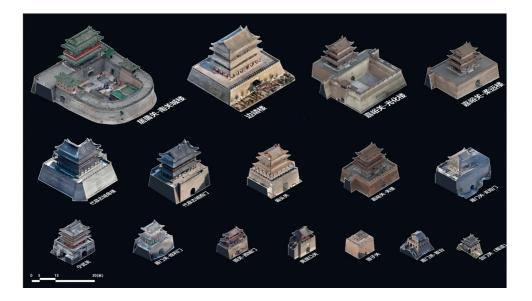
Tianjin University

This case focuses on the Great Wall which is a large linear cultural heritage site, addressing pain points like difficult data acquisition, insufficient value mining, and disjointed multi-scenario interpretation. It builds an intelligent digital workflow of information acquisition, intelligent analysis, value mining and multi-scenario application, exploring new paths for heritage protection and activation.

Technically, it uses UAV low-altitude aerial surveying to acquire over 2 million HD images and centimeter-level 3D data, builds a full-length real-scene 3D database based on WebGIS, introduces AI object detection and image segmentation to automatically extract spatial features, combines historical records to unearth implied values like hidden gates, auxiliary beacon towers, and colored sections, and produces resource statistics like watchtower distribution and steep wall sections.

➡ Building a Full Digital Intelligence Chain Solves Core Pain Points of Linear Heritage

This case uses UAV low-altitude aerial surveying to acquire data from hard-to-reach areas like ridges and deserts, obtaining over 2 million HD images and centimeter-level 3D data. A WebGIS-based real-scene 3D database helps manage massive data. AI-powered object detection and image segmentation automatically extract heritage spatial features and utilize historical records to achieve hidden values. Finally, multi-scenario application pays off, forming a solution covering the entire process of protection, research, and utilization, filling the gap in digital protection frameworks for large-scale linear cultural heritage sites.

➡ High-Precision Data Acquisition and Intelligent Management Strengthen Research Foundation

This case makes dual breakthroughs in data acquisition and management. Acquisition covers 7000 km of key wall sections, beacon towers, and forts, acquiring over 40TB of image data (excluding 3D models) with centimeter-level precision. Management uses WebGIS to build the Great Wall Real-Scene 3D Database System, integrating historical, cultural, and location information based on spatial positioning into a comprehensive digital database.

➲ AI-powered Value Mining Refreshes Understanding of the Great Wall

Introducing AI technologies like object detection and image segmentation, based on independently annotated datasets, enables automatic extraction of the spatial features of over ten thousand heritage units, completing multi-dimensional resource statistics and hidden value collection. Statistics accurately identify the top 5 steepest walls and densest watchtower sections; comparing images from different periods clarifies deterioration location, type, and severity, providing data for protection monitoring. Discoveries include identifying over 130 hidden gate remains and building a genealogy, filling the gap in the three-level system of passes, gates and hidden gates; categorizing beacon tower families reveals historical signaling scenes; discovering multi-colored sections in several provinces.

➲ "Trinity" Multi-Scenario Integration Innovates Value Interpretation Paths

Online
Cooperated with Tencent to develop the Cloud Tour of the Great Wall mini-program, covering 4000 km and generating 160,000 images. Visits exceeded two million in three days; page views totaled 15.6 million in three months.

In-Museum
Undertook exhibition design for museums like the Shanhaiguan China Great Wall Museum, creating the world's largest changeable sandbox; "Fly Over the Great Wall" five-sided screen digital exhibits; applied AR to make static models emit smoke, visually restoring beacon smoke scenes.

On-Site
Provided service for the upgrade of the Badaling scenic area and the design of the Shanhaiguan Great Wall National Cultural Park; developed mini-programs for smart identification and companion tours, achieving all-round transmission of heritage value.

➲ Interdisciplinary Integration Yields Abundant Results
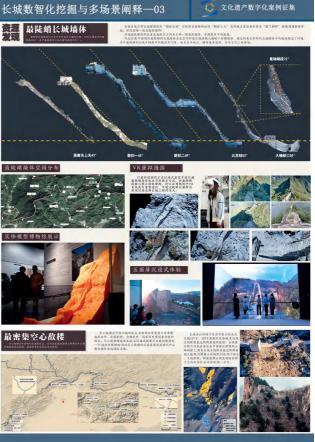
This case integrates multidisciplinary methods (architecture, humanities, IT), achieving significant theoretical, practical, and dissemination results. Theoretically, it established the Ming Great Wall "Order Belt" concept, compiled the first published over 130 papers, completed over 80 theses, and 31 research fund cases. Practically, results were applied in five Great Wall museums, aiding national cultural park construction. Publication included over 60 reports by renowned media; the mini-program of Cloud Tour of Great Wall and exhibitions reached over ten million people.

➲ Exporting Replicable Experience, Empowering Protection of Similar Heritage

The case refined two promotable experiences: 1) A method combining intelligent statistics and comparative analysis; 2) A collaborative multi-scenario activation model made up of three locations: online, in-museum and on site. Future work includes regular surveys to enrich the database; acquiring Shu Roads data in winter; supplementing periodic data and building a Shu Roads database; organizing knowledge graph data for the Great Wall and Shu Roads; developing knowledge fusion, reasoning modules, and interactive interfaces; developing tour service mini-programs based on the knowledge graph; formulating and providing multi-scenario digital value interpretation solutions for large cultural heritage sites based on museum experience; summarizing databases, knowledge graphs, and solutions; conducting academic cooperation on Hadrian's Wall and the Great Wall of China.

长城数智化挖掘与多场景阐释—02

文化遗产数字化案例征集

长城数智化挖掘与多场景阐释—03

文化遗产数字化案例征集

长城数智化挖掘与多场景阐释—04

文化遗产数字化案例征集

08

Natural Muon Imaging Technology Empowers the Protection of the Yungang Grottoes

▶ **Applicant Institution**

Yungang Academy

▶ **Participating Institution**

Tencent Technology (Beijing) Co., Ltd.;
Lanzhou University

The Yungang Grottoes face deterioration like weathering and water seepage. Traditional detection techniques are destructive or limited, creating an urgent need for non-destructive methods. This case focuses on applying natural muon imaging technology to grotto protection. Lanzhou University, together with the Tencent Tanyuan Plan and Yungang Research Institute, applied this technology. It utilizes cosmic ray muons' strong penetration capability for non-invasive 3D density imaging, akin to a CT scan for cultural relics.

➲ Technological Innovation: Green Nuclear Imaging Breakthrough Based on Natural Muons

The core innovation lies in using natural muons generated by cosmic rays interacting with earth's atmosphere as "probe rays," resulting in environmentally friendly detection with no pollution and no disturbance. Similar to medical CT principles, it deploys flat-panel muon detectors to capture flux variations of muons passing through the relic from different directions, inversing internal density distribution to generate 3D density images. This logic avoids the destruction caused by traditional techniques like drilling, providing a new paradigm for internal structure detection of large cultural relics.

➲ Detection Method Innovation: Non-Invasive "Perspective" Solves Non-Destructive Monitoring Challenge

This technology is non-invasive and no-contact, changing traditional methods reliant on excavation, drilling, or close contact. At Yungang Grottoes, detectors deployed inside or around the grottoes scan the internal cliff structure without drilling, sampling, or touching the relic itself. For example, it successfully inversed the shape and size of low-density areas in the Yungang Fort rammed earth wall, matching reality; scanning the facade of Caves 7-8 accurately located low-density anomaly areas from 20th-century repairs, verifying the ability to identify hidden structures. This long-distance, contactless method resolves the enduring contradiction between detection and protection.

➲ Application Scenario Innovation: From Structural Diagnosis to Preventive Conservation

This case breaks the "single-point, single-function" limitation of traditional geophysical techniques, building an application system consisting of structural imaging, hidden danger localization and long-term monitoring.

Structural Diagnosis

3D density imaging accurately identifies density anomalies inside relics (e.g., voids, cracks,

seepage channels). It discovered high-density rock mass below the west city wall in Caves 9-10, providing precise coordinates for subsequent surveys and it located potential collapse risk areas during a "physical check" on Xi'an city wall.

Preventive Conservation

The technology supports long-term dynamic monitoring: fixed detectors continuously track internal structural changes, and combine with AI algorithms to predict geological hazards, promoting the shift from passive repair to active prevention and control. This model extends the value from single detection to long-term management, becoming a core part of smart cultural preservation.

⮞ Industry-University-Research Collaboration: Cross-Domain Cooperation Accelerates Technology Implementation and Iteration

This case innovatively builds collaboration between research institutions, cultural preservation units and tech enterprises, achieving a seamless connection between R&D, scenario verification, and commercialization of scientific findings.

As technological researcher and developer, Lanzhou University provides core algorithms and equipment R&D capability for Muons. Yungang Research Institute provides relic background, field conditions, and professional knowledge.Tencent Tanyuan Plan provides funding, resource integration, and technology implementation scenario docking.

This tripartite collaboration accelerated lab-to-application transformation (e.g., quickly completing the 2023 Yungang Grottoes pilot detection) and promoted iteration – optimizing detector sensitivity and data inversion efficiency based on conservation needs, making it more suitable for complex scenes like grottoes and ancient walls. This model was included in the "Tanyuan Plan 2023" Top 20 Applied Technology Award.

⮞ Technology Expansion: Potential Usage from Cultural Relic Protection to Cross-Domain Applications

The innovative value of the technology extends beyond cultural relic protection; its core principle applies to multiple fields, showing strong cross-domain potential. In archaeology, besides Yungang Grottoes and Xi'an city wall, it was used to scan the Egyptian Pyramid of Khufu, discovering hidden chambers and corridors, promoting research into this ancient civilization. In industry, it can be applied to nuclear waste container monitoring, underground pipeline detection, dam safety assessment, etc. In geology, it can aid volcano research, glacier bedrock imaging, mineral exploration, etc. The technology was selected as an Excellent Typical Case for Future Industry Innovation Development 2024 by MIIT and was awarded the title "China Good Technology," it was also reported by many authoritative media outlets.

基于大数据的
古陶瓷基因库数字化平台

Digital Platform for Ancient Ceramic Gene Bank Based on Big Data

青花海水纹盘

09

Digital Platform for Ancient Ceramic Gene Bank Based on Big Data

▶ **Applicant Institution**

Jingdezhen Imperial Kiln Institute

This case innovatively constructs a digital system for "ancient ceramic genes," using big data and AI to achieve breakthroughs from multi-dimensional data acquisition and standardized management to active utilization of ancient ceramics. Its core value lies in the following:

1) Proposing the "ancient ceramic gene" concept, extracting multi-dimensional data like body, glaze, color, and patterns, establishing a standardized database with 1 million gene data entries, filling the gap in standardized digital resources.

2) Building a three-layer technical architecture consisting of infrastructure, application support and application, connecting scenarios like research, display, education, and industrial transformation, and forming a workflow of data, knowledge and application.

3) Innovating an 8+X data standard and knowledge graph, promoting cross-institutional sharing of ancient ceramic resources, providing precise data for academic research while preserving living cultural heritage through cultural creativity and immersive exhibitions.

➲ Transformation Needs and Challenges in Ancient Ceramic Digitization

Ancient ceramics research and protection are transitioning from traditional modes to systematic and digital transformation. Traditional methods rely on visual inspection and experience, facing three adaptation needs:

1) Information fragmentation which lacks unified standards and correlations makes it hard to establish a system.

2) Disconnect between scientific testing and art history research, lacking systematic scientific data for in-depth analysis.

3) Lagging digital platform development and the absence of cross-regional sharing mechanisms constrain the accumulation and innovative use of research outcomes.

Therefore, big data technology is needed to integrate multi-dimensional information, build standardized digital platforms, achieve precise acquisition, correlated management, and diverse application of ancient ceramic information, balancing traditional craft transmission and modern technological innovation.

➲ Building the Digital Technology System for Ancient Ceramic Genes

This case builds a three-layer technical system for systematic digital management.

Infrastructure Layer

Relies on hardware like security equipment, servers, storage devices, and reuses existing network facilities to provide basic support, ensuring data storage and transmission stability.

Application Support Layer

Through common components like process and image management, integrates data from archaeology, collections, specimens, literature, etc., and establishes unified data management modules, provides standardized data interfaces, achieving correlation and integration of multi-source information.

Application Layer

Provides differentiated services: opens research data application and retrieval for scholars; opens partial specimen data and knowledge graph visualization interface to the public to spread knowledge through keyword search and graph display.

➡ Implementation Path from Data Acquisition to Standardized Application

This case promotes digitization in phases, forming a replicable framework.

Consolidating the Digital Foundation

Systematically reviewed nearly 40 years of excavated fragments (20 million pieces), prepared 3000 sets (12,000 pieces) of specimens, formulated the *Ceramic Gene Bank Physical Sample Management Standard*, introduced flexible sample preparation robots for process standardization, laying the foundation for data acquisition.
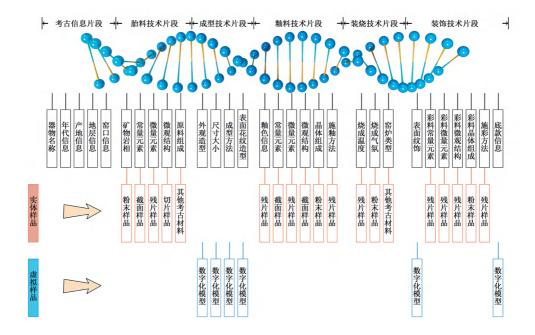
Intelligent Acquisition and Modeling

Focused on core features like patterns, colors, shapes, developed automatic zoning and semantic deconstruction technology, built high-precision 3D models, connected with the database to form semantic graphs, achieving data transformation from acquisition to structuring.

Quality and Sharing Mechanism

Established a verification system consisting of automatic identification , expert review and standard output for data accuracy; promoted cross-institutional data sharing, achieving compatibility and interoperability through unified standards.

➜ Diverse Application and Effectiveness of Digital Outcomes

This case has achieved significant results in research, dissemination, and industry.

Academic & Research Support

Provides precise data for archaeology and restoration to support multiple studies, formed a virtuous cycle of data application and outcomes feedback, enhancing scientific rigor and efficiency.

Cultural Dissemination & Education

Created the World Ceramics Interactive Map, visually presenting the global transmission of ceramics; launched the immersive exhibition *The Secret Realm of Blue and White Porcelain*, which received over a million visitors; built a study system consisting of basic cognition, professional practice and creative expression, transforming research resources into public education through interactions like microscope observation and custom pattern design.

Industrial Transformation & Economic Value

Developed IPs like Ducktor Sui; created over 20 cultural creative products; formulated the *Imperial Kiln Handmade Ceramic Craft Standard*, driving tie-in economic value exceeding 20 million RMB; applied for 16 patents and 20 copyrights, forming an income model integrating culture, technology and industry.

➲ Future Expansion Directions and Sustainable Planning

This case will promote sustainable development through technological innovation, scenario expansion, and international cooperation.

Technological Upgrades
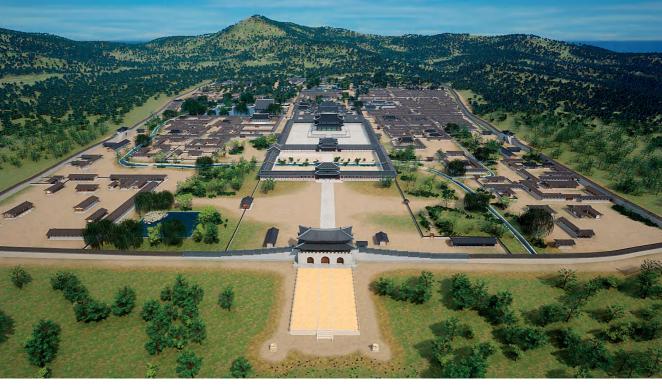
Refine data indicators for body, glaze, color, etc.; improve knowledge graphs and AI automatic recognition; enhance pattern and shape comparison precision; build interdisciplinary knowledge nodes for automatic data reasoning and correlation.

Scenario Extension

Promote deep data application in archaeological research, artifact restoration, digital exhibitions, etc.; expand international cooperation; promote global ceramic data sharing through the International Ceramic Research Alliance.

Resource Support & Risk Response

Seek special funding and social capital; form interdisciplinary teams; establish dynamic technology evaluation mechanisms and data security systems; use modular architecture to counter equipment iteration; prevent data misuse through encryption and permission management.

10

WIPCO: Gyeongbokgung Palace 3D Digitization Project

▶ **Applicant Institution**

WIPCO (Korean Digital Technology Company)

In recent years, the Cultural Heritage Administration of Korea has committed to recording and preserving cultural heritage, with a focus on the diverse needs of future content industries, completing the comprehensive digitization of Gyeongbokgung Palace. South Korea conducted 3D asset development for Gyeongbokgung to address the shortage of high-quality digital cultural heritage assets. The project restored its late Joseon Dynasty appearance based on historical records. Assets include various types like buildings and artifacts which were divided into component type and completed type, these are produced modularly following global standards, and are open for free use in multiple fields.

➜ Accurately Restoring the Historical Appearance of Gyeongbokgung Palace

Gyeongbokgung Palace is a representative of cultural heritage site in South Korea and the site of important historical events of the Joseon Dynasty. Although severely damaged during the Japanese colonial period, it commenced large-scale restoration projects from the 1990s, restoring the main parts. The project, based on historical records, survey reports, and 3D scan data from the Joseon period, completely recreates the original appearance of Gyeongbokgung from the late Joseon era. Existing buildings were produced by taking reference from the 3D prototype records of the Cultural Heritage Administration and combining literatures such as on-site measurement reports and restoration reports.

➲ Classification and Assembly by Structure, Enhancing Sustainable Value

3D assets are classified and structured according to architectural component units and provided in an easily assembled building module format. Users can not only recreate Gyeongbokgung Palace but also freely construct traditional buildings like Hanok according to their needs. By configuring according to content purpose, combining internal artifacts, terrain, and natural elements, a complete scene can be constructed. This method creates sustainable value for national heritage.

To make assets conforming to architectural norms, traditional architectural structure analysis was conducted, and a component library was designed. Modular production was adopted to maximize practical application convenience and support future expansion. Component modules can be divided into foundation parts, column parts, bracket set parts, upper framework parts, roof parts, and others. These modules, diversely combined according to purpose, can be reused repeatedly. Each module is a collection of elements like cornerstone stones, columns, walls, and windows.

➲ Technical Optimization, Enhancing Performance and Realism
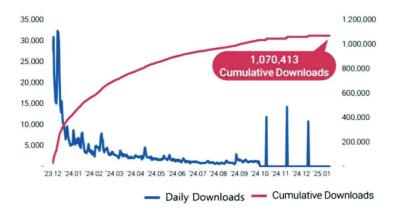
By utilizing raw data, an optimized dataset was constructed by balancing physical realism and real-time response performance. Lightweight techniques for interactive content and computational efficiency techniques for achieving realistic reactive content were employed. To support service environments like web and mobile, performance was optimized using Retopology, Normal Map, Texture Compression, and Texture Atlas technologies. To enhance realism and multi-purpose application, computationally efficient techniques meeting global standards were adopted: LOD (Level of Detail) – adjusting mesh precision to produce three-stage detail models; PBR (Physically Based Rendering) – applying PBR textures based on material properties to achieve realistic data representation.

➲ Wide Application, High Practicality

By expanding into various industries such as games, movies, VR/AR, and museum exhibitions, the 3D assets serve as an important link connecting preservation and creation. Gyeongbokgung 3D assets have already been applied in content for *Black Desert*, a game developed by South Korean company Pearl Abyss, providing a successful example of traditional architectural heritage naturally extending into popular culture content.

Furthermore, these digital assets hold broad appliation potential for future content. Their application potential and public value have benn verified through accurate research. Particularly, the Gyeongbokgung assets disclosure through the FAB market demonstrate high practicality in industry, academia, and among the general public, laying a foundation for building a sustainable digital content industry ecosystem for national heritage.

SURVEY & RECORD

DIGITAL DOCUMENTATION & VISUALIZATION

张园
ZHANG YUAN
石库门建筑群
数字孪生与多模态交互平台
DIGITAL TWIN AND MULTIMODAL INTERACTION PLATFORM FOR ZHANGYUAN SHIKUMEN ARCHITECTURAL COMPLEX

上海交通大学建筑文化遗产保护国际研究中心
International Research Centre for Architectural Heritage Conservation, SJTU

11

Zhangyuan Shikumen Architectural Complex Digital Twin and Multi-Modal Interactive Platform
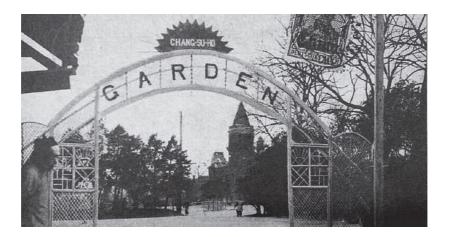
▶ ## Applicant Institution

International Research Center for Architectural Heritage Conservation, Shanghai Jiao Tong University

This case focuses on the digital conservation, activation and utilization of the Zhangyuan Shikumen architectural complex in Shanghai. Based on a graded surveying strategy, it integrates technologies such as 3D laser scanning and oblique photogrammetry to reproduce architectural forms and textures with millimeter-level precision, building a real-scene 3D model. On this basis, it has developed a B/S architecture digital twin platform with presentation, application, and data layers, integrating multi-source data to refine real-time building management, supporting operation, maintenance, repair, and early-warning scenarios. Simultaneously, it introduces multi-modal interactions such as AR overlay, VR tours, and AI digital guide avatars to create the application Buildings Can Be Read, enhancing public cultural perception.

Graded Surveying + Multi-Source Fusion Solve Modeling Challenges

To address issues of insufficient precision and missing information in traditional surveying caused by the elongated space and densely clustered buildings, the project adopted an innovative strategy of graded surveying combined with multi-source data fusion, building a modeling system covering three scales: district, individual building, and component detail. At the macro scale, drones with RTK modules were used for oblique photography to acquire district-wide data. At the meso scale, ground-based 3D laser scanning recorded individual building forms. At the micro scale, handheld laser scanning and high-resolution photography reproduced details such as carvings, achieving millimeter-level precision (detail texture fineness up to 5mm). A multi-source data fusion scheme formed a complete, precision-unified real-scene 3D model base, laying a precise data foundation for subsequent digital management and display.

➲ Full-Lifecycle Digital Twin Platform for Dynamic Management

The project built a three-tier digital twin platform based on a B/S architecture, consisting of a presentation layer, an application layer and a data layer. The Data Layer integrates diverse sources, including basic archives, 3D models, and sensor monitoring data, with permission controls to ensure security. The Application Layer covers modules such as digital twin visualization, property management, and monitoring/early warnings, supporting modular expansion. The Presentation Layer enables multi-role and multi-terminal access. Using the Cesium lightweight engine and SpringBoot framework, the platform achieves efficient 3D model rendering and real-time data interaction. It can dynamically update information flows such as building operation records and merchant activity data, and issue safety warnings based on risk assessment algorithms. This enables a transition in historical building management from static documentation to dynamic understanding and intelligent decision-making.

➲ Multi-Modal Interactive Design Deepens Cultural Value Interpretation

The project developed a multi-dimensional interactive system under the Buildings Can Be Read application. Drawing on historical materials, it reconstructed key historical scenes of Zhangyuan from 1900 and 1920. With AR scene overlay technology, the public can directly compare architectural changes across time. AI digital avatar semantic guided tours provide personalized explanation services. VR immersive tour functions were developed to present architectural details beyond temporal and spatial limits. This integration of the virtual and the real transforms static buildings into perceptible, participatory cultural carriers, not only enhancing public identification with Shikumen architecture and Haipai culture but also innovating cultural heritage dissemination paths.

→ Cross-Domain Integrated Technical Architecture Ensures Platform Adaptability and Extensibility

The project integrated technologies such as GIS, WebGL, and PostgreSQL to build a high-availability, cross-platform technical system. ArcGIS Server and the Cesium engine enable coordinated rendering of maps and 3D models. The CesiumLab slicing and compression tool optimizes model loading speed, ensuring efficient web browsing. The platform reserves interfaces for IoT terminal and AI module integration, allowing future expansion of functions such as sensor monitoring and intelligent recognition. Simultaneously, adopting a multi-line parallel concept of protection, management and operation, it offers customized functions for different entities, for instance, data interfaces for cultural preservation institutions and tour entry points for the public, meeting current multi-scenario needs while reserving space for future function upgrades.

➲ Significant Multi-Dimensional Practical Results Set a Replicable Benchmark

The project has delivered remarkable achievements in cultural, research, and social aspects. In cultural conservation, it completed systematic digital modeling of 43 historical buildings, achieving a transition from static protection to dynamic management, providing precise data support for protective development. In research transformation, it produced three core journal publications, won second prize in the Tianjihang Cup competition and developed transferable theoretical methods. In public communication, it was reported by multiple mainstream media outlets and selected as a a flagship case in the 2025 Shanghai Public Digital Literacy Enhancement Month.

➲ Forward-Looking Planning Layout Explores New Paths for Digital Governance

Building on current outcomes, the project has defined future directions to continuously enhance platform value. Technically, it plans to improve the monitoring indicator system, integrate large-model semantic recognition and knowledge graphs and create a queryable historical building knowledge system, transforming raw data into intelligent resources. In terms of user experience, it will optimize AR interactive applications, integrate city walk offline guided tours, building an online-offline integrated cultural experience model. Mechanistically, it will improve data authorization and open interfaces, enhance cross-departmental and cross-cycle collaboration capability. Ultimately it seeks to explore a digital governance path for historical blocks in urban core areas, offering reference for the protection of similar heritage.

——国家级非物质文化遗产代表性传承人记录工作成果展

主办单位：文化和旅游部非物质文化遗产司 国家图书馆
联办单位：各省级非物质文化遗产保护中心 各级各类图书馆

12

Recording Work for Representative Inheritors of National-Level Intangible Cultural Heritage

▶ ## Applicant Institution

National Library of China

This iniative integrates two major cultural heritage protection practices: digitization in small and medium-sized museums and systematic recording of intangible cultural heritage (ICH) inheritors in China. The core innovation lies in building a digital protection system that combines technical adaptation with systematic methodology. Through modular technical tools, such as digital cultural creativity and AI interaction, it solved the dilemma of resource shortage and inadequate digital capability in small and medium-sized museums, thereby revitalizing and disseminating cultural resources. On the other hand, through a working method of "3+1", including oral history, practice recording, teaching recording and literature collection, it systematically addresses the recording challenges of living ICH transmission, balancing the retention of tacit knowledge and technical details. Both approaches form a process of recording, activation and sharing, lowering the operational threshold through standardization while relying on technological innovation to keep cultural heritage vibrant in the digital age.

➔ Practical Needs and Challenges in Cultural Heritage Digitization

The field of heritage protection faces dual challenges of sustaining living transmission and achieving technical adaptation. In the museum sector, despite significant growth, small and medium institutions often lack resources and professional expertise, leaving them behind in digitization. As a result, they remain bound by traditional dissemination models and unable to fully unlock the value of their collections.. In the ICH field, the skills and wisdom of inheritors are the essence of living heritage, but most inheritors are elderly. Conventional recording methods are often fragmented, failing to completely capture tacit knowledge like physical details and interactive experience, leaving a risk of knowledge loss over time. How to use digital technology to both respect the authenticity of cultural heritage and achieve its sustainable transmission and broad dissemination becomes a key issue requiring breakthrough.

➔ Innovative Practices in Technology Empowerment and Systematic Methodology

The two project types respectively use modular tools and systematic processes to build digital protection paths.

Modular Breakthroughs in Small/Medium Museum Digitization

Relies on customized modules such as digital cultural creativity, WeChat mini-programs, video dissemination to provide tailored services. For example, AI-based interactive products like Starry Time Mirror animate artifacts and allow users to participate in cultural creation. Video account toolboxes helped build a communcation matrix, achieving 35.8 million views and driving a 39

percent increase in participating institutions' follower. Joint cultural and creative competitions produced 2,246 design works, many of which were implemeted. A the same time, training programs benefited 8,000 practitioners, lowering the digital threshold.

Systematic Recording of ICH Inheritors

At its core is the "3+1" methodology: oral history documents personal experiences and key insights; practice recording captures complete operational processes; teaching recording preserves characteristic pedagogical methods; and literature collection builds personal archives. Supporting these are standarized work norms and operation guidelines, reinforced by nationwide training programs. To date, records of 1,279 inheritors have passed acceptance checks, forming a standardized practice system.

➡ Value Transformation Path from Preservation to Activation
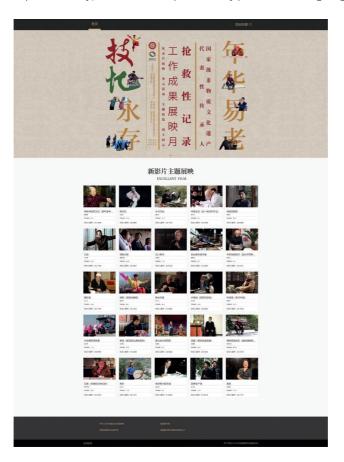
Both project types go beyond mere preservation, building a cycle of recording, dissemination and application.

Two-Way Interaction in the Museum Field

AI technologies transform artifacts from static exhibits into interactive carriers. Users can both participate in Q&A experiences for transmission and act as "digital craftsmen" co-creating cultural products. Through the Tanyuan platform, digital resource licensing and transactions form a cycle of cultural resources, digital innovation and industrial transformation, for example, excellent designs from the Sanxingdui Museum have been put into production.

Multi-Dimensional Dissemination in the ICH Field

Online, recording outcomes are made accessbile through thematic websites and new media matrices; offline, activities like screening months and lecture months are held in collaboration with hundreds of institutions. Recording materials have been converted into books, courses and other formats, providing firsthand data for research while allowing the public to better understand ICH value. By 2025, over 75,000 hours of ICH recording materials had been collected. After 397 recorded inheritors passed away, their skills were permanently preserved through digital archives.

➲ Practical Results and Future Development Directions

The two project types have achieved significant results. For museums, 362 institutions completed digital enhancement, covering over 80 prefecture-level cities, boosting both cultural dissemination and operational capacity. For ICH, over 20,000 hours of audio-visual literature and 470,000 documentary materials have been generated, effectively mitigating the risk of knowledge loss.

Looking ahead, efforts will continue to deepen. In the museum field coverage is planned to expand to over 1,000 institutions by 2026, with exploration into cutting-edge scenarios such as the metaverse. The ICH field will advance recording of remaining inheritors, introduce technologies like 4K filming and AI-assisted techniques, improve digital resource libraries, promote international exchange and cooperation, allowing digital protection experience to be more widely applied.

THE ROYAL DRESDEN PORCELAIN COLLECTION

PORCELAIN MEETS HISTORY

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The Royal Dresden Porcelain Collection Platform

▶ **Applicant Institution**

Porzellansammlung, Staatliche Kunstsammlungen Dresden (SKD)

▶ **Participating Institution**

Robotron GmbH, TBO INTERACTIVE GmbH & Co. KG

This case innovatively builds a tripartite digital system for porcelain collections that integrates physical objects, historical documents and a digital platform. Core breakthroughs include:

First, linking 8,200 East Asian porcelain pieces (late 16th to early 18th centuries) with well-preserved 18th-century original inventory catalogs, enabling tracing of object and document provenance through digital technology, offering unique perspectives for cross-cultural research.

Second, creating multi-dimensional digital catalogs (scholarly catalog, historical literatures catalog, visual catalog), supporting multi-language (including Chinese) access and open download of high-resolution images, balancing academic rigor and public accessibility.

Third, connecting over 700 dispersed pieces worldwide, building a virtually reconstructed network of the Royal porcelain collection, providing a platform for the digital preservation and global sharing of complex historical collections.

➲ Core Needs and Challenges in Porcelain Collection Digitization

The East Asian porcelain collection of the Dresden State Art Collections' Porcelain Collection is globally unique. It encompasses 8,200 objects (originally about 29,000) and preserves the original inventory catalogs compiled in the 18th century (nearly 2,500 pages), with precise correspondences between objects and documents via "palace numbers". However, such large-scale, intricately related collections face challenges in traditional research and dissemination:

First, the volume of objects and complexity of documents make comprehensive presentation in traditional publications unfeasible.

Second, more than 700 related objects scattered across over 80 institutions in 15 countries lack systematic correlation.

Third, funding requires integrating multiparty resources (foundations, private sponsors, etc.) to support large-scale digitization and academic organization.

To address this, this case uses a digital platform to overcome temporal and spatial limitations, enabling complete presentation and global sharing of the collection.

➡ Construction and Core Functions of the Digital Platform

This case spent over a decade building the Royal Dresden Porcelain Collection platform, achieving digitization through systematic preparation and multi-dimensional design.

Preliminary Foundational Work
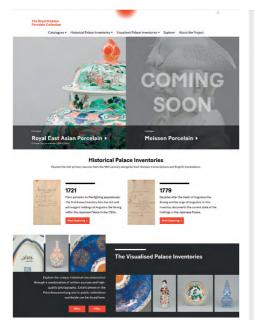
Completed 36,000 high-definition photographs of objects (including multi-angle views); digitized, transcribed (German), and translated (English) the 1721 and 1779 original catalogs (six volumes, nearly 2,500 pages); identified the "palace numbers" of 8,000 extant objects, establishing correspondence with historical documents; organized over 2,000 Chinese and Japanese porcelain marks, classified them by origin and period, and linked them to corresponding objects to facilitate comparative study.
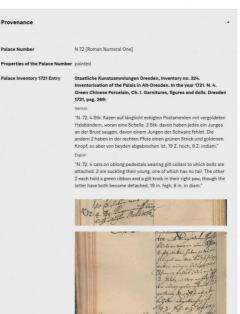
Three Core Catalogs

First, Royal East Asian Porcelain Scholarly Catalog: Integrates the latest research findings, presented through thematic introductions and object entries. Each entry includes provenance history (linking to original documents), references, and supports Chinese display of basic information.

Second, Historical Palace Collection Catalog: Digitally presents original documents, with transcription view (German/English), page zoom and detail viewing functions.

Third, Visual Palace Collection Catalog: Embeds object images into historical catalog entries, visually restoring the collection's original appearance, identifying dispersed objects and linking to related global holdings.

➲ Innovative Practice and Application Value

This case achieves multiple innovations in digital integration and academic dissemination.

Cross-Dimensional Correlation

By binding objects, historical catalogs, and provenance information via "palace numbers," the platform allow users to move seamlessly between the scholarly catalog, historical documents, and the visual catalog, forming a multidimensional pathway: examining object details, tracing history through documents, and visualizing the collection as a whole.
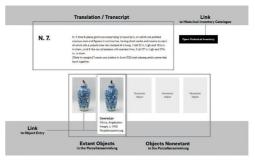
Global Resource Linkage

A dedicated Global Royal Dresden Collection section incorporates information on over 700 dispersed objects worldwide, inviting participation from institutions across the globe to gradually build a complete virtual collection network.

Openness and Adaptation

All high-resolution images are available for free download under Creative Commons licenses. The platform is adapted for desktops, tablets, and mobile devices, catering to both scholar research and popular science needs, becoming a core digital resource for research on cross-cultural material exchange.

➲ Practical Results and Future

Since its launch, the platform has become an important digital infrastructure for international porcelain research, with its innovative methods widely recognized.

Academic and Dissemination Value

It provides authoritative digital materials for research on East Asian export porcelain and European collection history; supports specialized research like mark comparison and provenance tracing. The multi-language design and open-access model lower the access threshold for global users, fostering cross-cultural understanding.

Future Expansion

Plans to complete the scholarly catalog for Meissen porcelain (Europe's first hard-paste porcelain), further link globally dispersed objects; invite more institutions to participate in the digital network, continuously enriching the platform's research and educational functions.

基于无人机倾斜摄影建模的
新疆佛寺遗址数字化采集与记录

Digital Collection and Documentation
of Buddhist Temple Ruins in Xinjiang Based on Drone
Oblique Photogrammetry Modeling

14

Digital Collection and Documentation of Buddhist Temple Ruins in Xinjiang Based on Drone Oblique Photogrammetry Modeling

▶ Applicant Institution

Fudan University Research Center for Land and Cultural Resources
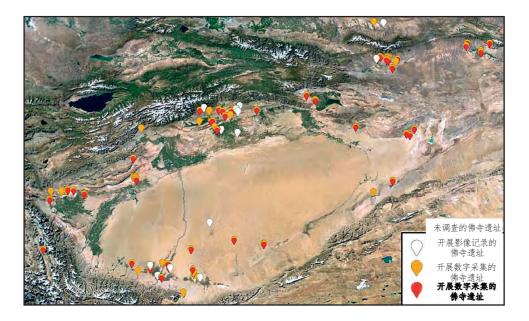
▶ Participating Institution

Zhongkan Huatong Archaeology Technology Co., Ltd.;
Xinjiang Uygur Autonomous Region Bureau of Cultural Heritage

Xinjiang's Buddhist temple sites, primarily earthen sites, face challenges like wind and water erosion. Addressing the issues of outdated and fragmented site documentation and their aggravated endangered state, this case focuses on the digital protection of over 100 above-ground Buddhist temple sites in Xinjiang. In July 2021, the Xinjiang Department of Culture and Tourism commissioned Fudan University and Zhongkan Huatong to initiate a special survey, completing the digitization of 82 sites over three years. Guided by the principles of cultural landscape and settlement archaeology the project integrated technologies like DJI drones and RTK positioning to achieve full-scale data acquisition from macro site groups to micro architectural textures, generating centimeter-level 3D models and orthophotos. It built a collaboration mechanism between universities, local cultural preservation departments, and tech companies, ensuring academic rigor and technical implementation. The project captured over 80,000 images, built a database exceeding 15TB, including 3D models of 53 sites and 252 architectural units, providing data support for protection decision-making; filled the gap in above-ground Buddhist remains in Xinjiang, enhancing academic discourse power; laid the foundation for digital cultural creativity and smart management.

➡ Comprehensive Data Acquisition Builds a Complete Heritage Information System

This case breaks through the single-point recording limitation of traditional archaeological surveys. Guided by the theories of cultural landscape and settlement archaeology, it conducted comprehensive data acquisition for 82 Buddhist temple sites within their natural geographical units and historical human environments. It recorded not only the site but also simultaneously preserved information on the surrounding natural environment and associated relics like city sites and beacon towers, avoiding the separation of site and environmental information. The project captured over 80,000 images, generated 43 high-precision orthophoto maps, built a structured 3D model and image database totaling over 15TB, promoting the upgrade of cultural heritage digitization from fragmented comprehensive.

➡ Multi-Technology Fusion Achieves Precise Full-Scale Data Coverage

Addressing Xinjiang's complex environment, this case integrated multiple technologies to form full-scale data acquisition capability. Hardware used equipment like DJI Matrice 300 RTK drones (45MP) and Zhonghaida Beidou TS5 (mm-level RTK positioning) to adapt to harsh conditions. Software used Agisoft Photoscan to integrate multi-source images, generating centimeter-precision 3D models and orthophotos through processes like control point calibration. Completed high-precision modeling of 53 sites, 252 architectural units, and 55 key areas, systematically recording basic information like site geology, landforms, and pathology and disease for the first time, providing precise data basis for formulating differentiated protection plans.
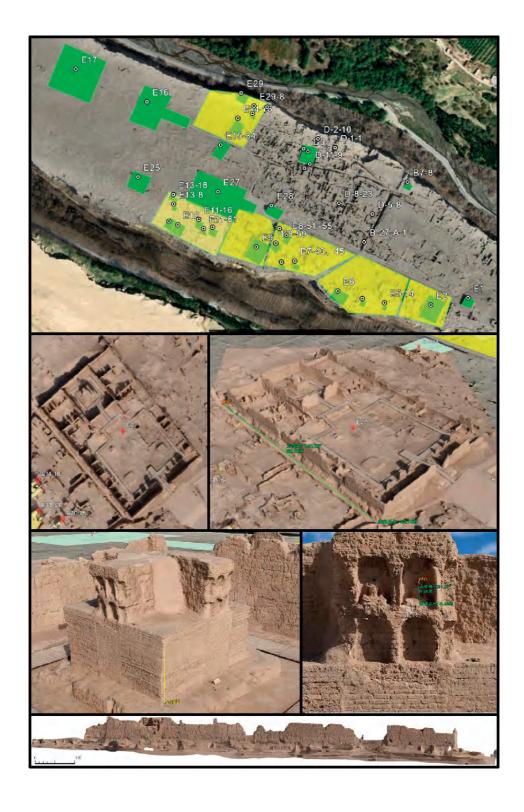
➡ Cross–Entity Collaboration Mechanism Balances Academic and Practical Value

This case broke the model of sole leadership by a tech company, building a tripartite collaboration mechanism between universities, local cultural preservation departments, and tech companies. The Fudan team set academic standards and controlled the research direction Xinjiang local cultural preservation departments provided basic information and communication coordination; Zhongkan Huatong was responsible for technical implementation. The project efficiently completed the survey of 82 sites in 272 days, fully demonstrating collaborative efficiency, providing a reference for organization and implementation of similar projects.

➡ Multi–Dimensional Application of Results Offers Both Protection and Development Value

The results deliver benefits across multiple dimensions. Protection-wise, high-precision data provides scientific basis for site reinforcement, reducing decision-making blindness. Research-wise, it fills the gap in above-ground Buddhist remains in Xinjiang, reversing the passive situation of relying on records by foreign explorers; results can fuse with grotto protection outcomes to promote academic breakthroughs. Industry and dissemination-wise, the 15TB digital assets lay the foundation for VR/AR experiences and cultural creativity development, enhancing China's academic discourse power.

➲ Replicable Practice Framework Adaptable to Multiple Heritage Scenarios

This case advanced a three-part protection framework encompassing theoretical methods, technical tools, and organizational mechanisms, directly reusable for Xinjiang's ancient cities, beacon towers, and other earthen sites. It also adapts to large, dispersed cultural heritage groups in harsh environments nationwide, like transnational Silk Road sites, effectively solving common industry problems like difficult surveying in remote areas and low data utilization.

Future work will proceed in three stages: short-term (2024-2026), mid-term (2026-2027), and long-term (starting 2028). The short-term plan involves building the Xinjiang Buddhist Temple Site database, integrating digital models and basic information of 82 sites, and developing a web-based query system for trial use by academia and cultural preservation institutions. Simultaneously, it will explore the historical, scientific, and artistic values of the sites from multiple perspectives and publish the monograph *Compilation and Research on Archaeological Materials of Xinjiang Buddhist Temple Sites*.

The mid-term plan will expand VR/AR application scenarios, achieve digital roaming functions for 5 sites, develop primary and secondary school heritage education courses, and explore diverse display methods using 3D printing and virtual reality technology.

The long-term plan involves joint research with Central Asian countries, promoting digital resource sharing of Silk Road Buddhist sites, and building a Digital Silk Road virtual exhibition hall.

方言保护计划

用 AI 留下你的乡音

15

AI-Powered Public Service Platform for Dialect Protection

▶ **Applicant Institution**

FLYTEK Co., Ltd.

▶ **Participating Institution**

Chongqing China Three Gorges Museum;
SHENLOUZHI STUDIO

Against the backdrop of endangered languages globally and the survival challenges faced by some lesser-known Chinese dialects, a comprehensive public service platform for dialect protection has been established. This initiative leverages policy support from China's national Language Resources Protection Project and the 14th Five-Year Plan for Cultural Development, alongside the technological expertise of iFLYTEK in large-scale AI models and speech technologies. The platform integrates data collection, academic research, and technological application.This case involved the development of the "I Speak Dialect with AI" mini-program to create a public-participation ecosystem for dialect data acquisition, addressing critical bottlenecks in data collection. Research on AI adaptability for non-mainstream languages was conducted to strengthen academic foundations. Breakthroughs in core technologies were achieved through the development of three AI systems for dialect recognition, synthesis, and translation. The platform is structured around a six-layer architecture, encompassing visual and application layers, among others.

➡ Living Transmission Needs for Dialect Protection

Dialects, as core carriers of regional culture, are facing transmission challenges under globalization and urbanization:

1. Difficulty in preserving living speech resources Dialects are highly localized and diverse. Traditional offline collection is costly, inefficient, and unable to meet large-scale data demands.

2. Insufficient technical adaptation Most dialects are "non-mainstream languages," lacking mature smart speech systems for recognition, synthesis, translation, constraining research and application.

3. Limited transmission scenarios Traditional protection mainly relies on static archiving, with low public participation, making it difficult to curb the decline in daily use. Therefore, the project uses AI as the core to establish a full-chain system covering acquisition, research, application and dissemination, shifting dialect protection from "salvage recording" to living transmission.

➡ Public-Participation Dialect Data Acquisition Ecosystem

The project has overcome data collection bottlenecks by creating a low-cost, high-participation mechanism.

Lightweight Acquisition Tools The *I Speak Dialect with AI* WeChat mini-program was launched with incentive mechanisms such as regional rankings and "like" rankings. Users can easily submit dialect speech samples and spread participation through social sharing, ensuring stable traffic growth. An official website was also built to aggregate academic research, industry information, and training resources, opening up new channels for information exchange.

Results By the end of 2024, nearly one million people had contributed more than 1.7 million dialect recordings, covering a wide range of regions and types. This laid a solid foundation for subsequent technological development and academic research, addressing the core challenge of data scarcity in dialect protection.

➲ AI-Driven Dialect Research and Application

The project focuses on adapting AI technologies to non-mainstream languages, strengthening the technical foundation for dialect protection.

Linguistic Research and Classification Dialects are categorized into three types of non-mainstream languages: spoken and written, written but rarely used, endangered and unwritten. Targeted studies were carried out on phonological structures (initials, finals, tones), syntax, and sound change patterns, while establishing correspondences with mainstream languages to provide a linguistic basis for technology development.

➲ Three Major AI Systems

Dialect Recognition System Based on the Spark speech large model and optimized with real user data, the system achieved recognition of 202 dialects, overcoming difficulties with complex dialects like Wu.

Dialect Synthesis System Using deep learning algorithms alongside syntax and tone change research, the system synthesized 20 dialects (e.g., male and female voices for Suzhou dialect) with MOS scores exceeding 4.0.

Dialect Translation System Optimized Neural Machine Translation (NMT) models enabled accurate translation from dialects to Mandarin (e.g., Cantonese, Wuhan dialect), addressing cross-language communication barriers.

➲ Scenario-Based Dissemination and Inclusive Applications

By innovating across diverse scenarios, the project has promoted the integration of dialect protection into public life, enhancing both social benefits and cultural dissemination.

Dissemination Matrix Collaborations with 60 celebrities and 1,500 dialect speakers produced variety shows such as *Dialect Heroes* and *Dialect Conference*. Initiatives such as "Dialects Enter Campus" and museum exhibitions in Shanghai and Suzhou further stimulated public participation. AI-powered short films (*Tales of Gusu*) and sound exhibitions at the Chongqing Three Gorges Museum (featuring 70 dialect exhibits) made dialect culture audible and tangible.

Inclusive Applications The iFlytek Input Method integrated recognition for 202 dialects and five minority languages, freely available to the public. Technical solutions were also provided for enterprises and government institutions, with applications in cultural tourism, media, and beyond (e.g., AI-powered dialect anchors), expanding usage scenarios and bridging the digital divide.

Future Planning and Sustainable Development
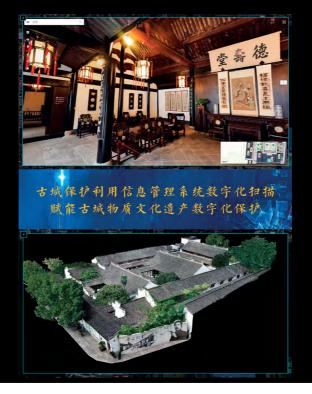
The project will continue to advance technology and scenario innovation, moving dialect protection toward greater systematization and normalization.

Endangered Dialect Rescue In collaboration with the National Language Protection Project, surveys will be conducted on 68 endangered dialects with fewer than 10,000 speakers, supported by dynamic monitoring. A digital dialect museum will also be built to provide a shared resource platform.

Technology and Scenario Upgrades Efforts will be made to further optimize AI models for complex dialects and expand applications in cultural tourism and education (e.g., dialect study programs). A "technology–culture–business" model will be explored, using commercial revenues to reinvest in protection efforts and ensure sustainable operations.

International Applications With mature technology and operational systems, the project aims to contribute to global living language protection, helping safeguard linguistic and cultural diversity worldwide.

古城保护利用信息管理系统数字化扫描
赋能古城物质文化遗产数字化保护

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Digital Scanning for the Protection of Ancient City Heritage

▶ **Applicant Institution**

Office of Shaoxing Historical and Cultural City Protection

This case establishes a digital protection system for tangible cultural heritage in an ancient city through a digital twin and multi-department collaboration. Key breakthroughs include:

1. Comprehensive 3D Modeling. Using UAV remote sensing and SLAM scanning, city-wide 3D real-scene models were created with millimeter-level precision and dynamic updates. Digital archives were established for 13 categories of traditional resources, addressing the lack of a clear "inventory" for protection.

2. Cross-Department Data Integration. A shared information platform integrates data from 14,787 buildings and over 30 types of public resources, enabling "one-map" visualization for planning and landscape management, breaking through departmental data barriers.

3. Virtual–Physical Integration. Construction plans are embedded into the 3D base map, allowing simulation and assessment from dimensions such as view corridors and control zones. This shifts decision-making in heritage protection from experience-based judgment to data-driven management, offering replicable technical and management methods for digital protection of other ancient cities.

➡ Needs and Challenges in Digital Protection

Shaoxing ancient city, with over 2,500 years of history and strong continuity of city site and cultural context, faces challenges in protection and utilization.

1. Incomplete baseline data: Records for heritage assets (e.g., taimen courtyards, ancient bridges) are missing or inaccurate, limiting precise protection.

2. Lack of repair blueprints. Brick-and-wood structures are highly vulnerable to fire and collapse. Existing construction records are fragmented, posing risks for restoration.

3. Week coordination. Development projects lack intuitive tools for planning and townscape management, reducing the effectiveness of multi-department collaboration.

Therefore, this case uses digital technology to build a system of comprehensive documentation, precise decision-making and collaborative management, upgrading the protection model.

➡ Technical Framework and Implementation

The protection framework is built on 3D modeling, data integration and intelligent decision-making.

Technical Support By Integrating BIM and GIS, UAV remote sensing is used for regular city-wide updates and monthly surveys of key blocks, generating 3D real-scene maps. High-precision modeling of 99 cultural protection units and 55 historical buildings was completed with laser point cloud scanning and SLAM smart robots, authentically restoring the ancient city's structure and appearance.

Data Integration A cross-department sharing information platform aggregates data from 13 categories of traditional resources and over 30 public facilities, forming a unified resource map and achieving management of geographic, historical, cultural, planning, and other information. A data resource center provides centralized storage, release, and sharing, improving data utilization.

Decision Applications Construction projects are implanted into the 3D map for multi-dimensional analysis (e.g., control zones, view corridors), supporting planning decisions for 19 major projects covering over 300,000 sqm, ensuring coordination of the ancient city's appearance.
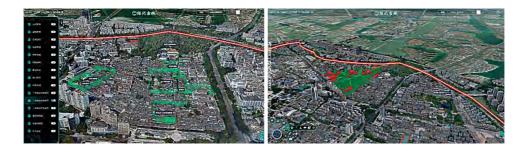
Innovation in Technology and Management

This case achieved several innovations in technology and management.

Multi-Modal Data Acquisition UAV oblique photography and LiDAR to acquire multi-source data enabled rapid, integrated modeling of indoor and outdoor scenes, capturing complex ground details in the ancient city and solving challenges such as crowd density and building occlusion.

Spatio-Temporal Semantic Parsing Deep learning algorithms were applied to extract building features, repair details, and build cross-modal spatio-temporal models, linking data with different precisions and enhancing modeling completeness.

Collaborative Management Mechanism Data standards were formulated for interfaces and formats, enabling "one platform, multi-department collaboration." This shifted management

away from isolated practices, promoting real-time data sharing and joint operations among planning, cultural relics, and other departments.

➲ Practical Results and Application Value

The project delivered significant results, becoming a model for digital protection of ancient cities:

Data Achievements Image and attribute data for 14,787 buildings were collected, 30.88 km of historic streets were scanned, and a dynamic digital twin base was established, achieving holographic recording of the city's heritage fabric.

Decision Support Providing scientific planning support for 19 major projects, avoiding conflicts between construction and heritage protection, and improving precision in townscape management.

Industry Recognition Won the 2022 World Smart City Award, and the Geographic Information Science and Technology Progress Award, and selected as a typical case by China's Ministry of Housing and Urban-Rural Development and Ministry of Natural Resources. The technical and management experience generated by the project has been adopted by other ancient city sites.

➲ Future Planning and Sustainable Development

The project will continue to enhance digital protection capability.

1. Improve data standards, expand the scope of resources entered, maintain real-scene documentation and dynamic updates, and improve data-sharing efficiency.

2. Strengthen system operations, optimize platform functions with IoT integration, expand application scenarios, and promote the transition from digital recording to intelligent governance in ancient city protection.

17

AMD × Yongle Palace: AI Empowers Cultural Relic Digitization, Revitalizing Millennia-Old Murals

▶ **Applicant Institution**

Advanced Micro Devices, Inc. (AMD)

▶ **Participating Institution**

Yongle Palace Mural Conservation Research Institute;
Shengshu Technology;
BOE Technology

The *Chaoyuan Tu* (the painting of the heavenly court) murals in the Sanqing Hall of Yongle Palace are the pinnacle of Chinese Yuan Dynasty (1271–2368) mural art. After 800 years of exposure, the murals face challenges such as color flaking, line breakage, and overpainting from the Ming and Qing dynasties (1369–1911) that obscure their original Tang and Song appearance. This case uses AI and computing power to digitally preserve the murals. An AI-based restoration system was jointly developed,, utilizing devices with different processor–GPU configurations to conduct data acquisition, feature extraction, model training, and staged restoration. The system significantly improved efficiency while achieving millimeter-level precision.

➡ Technical Framework Innovation: End-to-End AI Restoration System

An AI architecture covering the full workflow—acquisition, annotation, inference, training, output—was established. Multi-level computing power was integrated to support the entire restoration process. AI terminals enabled precise color and line feature annotation, feature extraction, professional inference, model training, and missing-part completion, forming a closed-loop system from data collection to precise restoration. This framework overcame the fragmented, step-by-step limitations of traditional manual restoration methods, integrating millimeter-level color calibration and brushstroke restoration into a unified technical system, and providing standardized technical support for large-scale mural digitization.

➡ Efficiency and Precision Innovation: AI-Driven Leap in Restoration Performance

The project broke through the limitations of traditional manual restoration, achieving dual leaps in both restoration efficiency and accuracy through an end-to-end AI solution. The restoration cycle of a single deity was reduced from several months to just hours. Restoration of the entire east wall mural was shortened by 98 percent, improving efficiency

nearly a hundredfold. At the same time, the system achieved millimeter-level color calibration, faithfully restoring the mineral pigment layers of the Tang and Song dynasties and the flowing "Wu Dai Dang Feng" line style, while even correcting mis-restorations from the Ming and Qing periods. This combination of high efficiency and high precision directly addressed the core pain points of conventional mural restoration—time intensity and technical difficulty.

➡ Collaboration Model Innovation: Cross-Sector "Tripartite Synergy"

This case pioneered a collaborative model uniting a tech enterprise, a technology company, and a cultural heritage preservation institution, creating a restoration ecosystem. AMD provided computing equipment and technical expertise; Shengshu Technology contributed image generation algorithms; and the Yongle Palace Mural Preservation Research Institute provided cultural relic conservation knowledge and restoration standards. Together, they established a digital studio and restoration lab, achieving deep integration of hardware resources, algorithmic capability, and conservation experience. This cross-sector approach bridged the gap between cultural preservation and

technology, transforming individual institutional limitations into systemic advantages,, and providing a replicable cooperation paradigm for similar cultural heritage digitization projects.

➲ Implementation Path Innovation: Phased and Adaptive Strategy

The project adopted a progressive three-stage path—initiation, breakthrough, and expansion—ensuring both quality and progress were well controlled. This phased focus strategy secured key outcomes at each stage, while allowing for dynamic model optimization based on early feedback, thus adapting to the varying needs of mural restoration, from local details to large-scale precision.

➲ Application Ecology Innovation: Full-Chain Value Release from Restoration to Cultural Revitalization

Going beyond the traditional concept of restoration as an endpoint, the project established a "restoration-dissemination-re-creation" value chain. Results were showcased at UNESCO in Paris and broadcasts on CCTV galas, reaching hundreds of millions of people. Nearly 1,000 derivative works were created through the Zcool platform's AIGC creative competition, transforming cultural heritage protection from a specialized activity into public participation. Meanwhile, it stimulated new industries such as digital cultural creativity and cultural tourism integration. Restoration results thus became not only permanent digital archives but also core materials inspiring the creative transformation of traditional culture, broadening the value of cultural heritage digitization.

➲ Sustainable Mechanism Innovation: Data-Driven and Dynamically Iterated

A sustainable mechanism combining standardized data acquisition with dynamic model iteration was established. Standardized processes ensured high-quality data collection and annotation for AI model training, while algorithms were continuously refined based on restoration feedback. This enabled models to adapt to different mural styles and damage characteristics, avoiding static technical solutions and ensuring continuous evolution of AI restoration capabilities with data accumulation and scenario needs. The mechanism guarantees long-term adaptability for digital cultural heritage protection.

The project will continue to advance the application of cutting-edge technologies such as AI in cultural heritage protection. It will pursue innovation and optimization based on practical needs, further improving the precision and efficiency of digital restoration. It will also expand the use of digitization outcomes into more application scenarios, deepen cooperation with relevant institutions, and open new channels for cultural dissemination. Upholding the principle of openness and sharing, the project will actively engage in international exchanges and cooperation in the cultural heritage protection field, share best practices in cultural relic digitization, and contribute to exploring effective global pathways for cultural heritage preservation.

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Integrating the Book and the Pavilion: A Public Welfare Digital Heritage Project

▶ ## Applicant Institution

Ant Group CO., Ltd.

▶ ## Participating Institution

Zhejiang Library

This case pioneers an activation system for ancient books and ancient buildings through digital technology combined with a public welfare model. By applying high-precision restoration, immersive experiences, and interactive dissemination, it achieves a "digital reunion" of the Wenlan Pavilion and the *Siku Quanshu* (*Complete Library of the Four Treasures*). Its core value lies in:

1. Breaking physical barriers by using digital tools such as 360-degree virtual tours and high-definition scanning to reconcile the tension between ancient book preservation and public accessibility, allowing rare cultural treasures to be shared beyond collections.

2. Lowering the comprehension threshold through AI digital guide avatars and AIGC-generated generation scenes, offering companion reading, explanations, and interactive tasks to enhance public engagement.

3. Innovating a tech volunteer model, with over 60 young technologists contributing, forming a replicable "public welfare + technology" paradigm for cultural dissemination, and providing a lightweight, inclusive solution for the digital transmission of traditional culture.

➦ Digital Transmission Needs for Ancient Books and Ancient Buildings

The Wenlan Pavilion and *Siku Quanshu*, as significant cultural heritage assets, carry rich historical wisdom but face challenges in contemporary transmission. Preservation needs limit physical display of ancient books, creating a contradiction between collection and use. The content of ancient books, written primarily in classical Chinese, is difficult for the general public to access and understand. Traditional dissemination methods are static and lack interactivity, failing to spark public interest. Additionally, low OCR recognition rates for ancient books and time-intensive manual proofreading constrain digitization, which would otherwise take decades. Therefore, digital technology is needed to integrate ancient building and ancient book resources, enhancing accessibility and dissemination while protecting and safeguarding cultural value and embedding it into modern life.

➦ Digital Technology Building a Cultural Transmission System

The project integrates multiple technologies to establish a system of restoration, interpretation

and interaction, digitally revitalizing cultural heritage.

High-Precision Digital Restoration Real-scene photography and optimization recreated a 360-degree virtual Wenlan Pavilion, restoring architectural detail. Non-destructive scanning of the *Siku Quanshu*, combined with multilingual OCR technology (achieving over 90 percent accuracy),, enabled online browsing and content extraction, overcoming physical preservation limits.

Immersive Scenes and Interpretation AIGC-generated seasonal landscapes of Wenlan Pavilion and virtual study settings enhanced immersion. Ant's proprietary digital human technology provided guided tours and companion reading, using accessible language to interpret historical context and ancient book content, reducing the barrier to understanding.

Interactive Dissemination Design Gamified tasks (e.g., badge collection) were embedded in the Alipay mini-program, combined with AntChain digital souvenirs to incentivize sharing. Social interaction design broadened influence, transforming users from passive viewers to active participants.

➲ Implementation Path: From Acquisition to Dissemination

The project advanced in four stages, forming a closed-loop system of digital transmission.

1.Digital Acquisition Real-scene photography and virtual modeling of Wenlan Pavilion; high-definition scanning of *Siku Quanshu*; OCR recognition and image repair laid the foundation.

2.Virtual Exhibition Development Construction of the virtual Wenlan Pavilion with AIGC-generated seasonal landscapes; embedded ancient book content into virtual study scenes enabled interactive experiences such as book selection and page turning.

3.Intelligent Interpretation Training digital humans for guided tours and companion reading; applying large models to optimize ancient book proofreading and translation; and assisting comprehension of professional content.

4.Public Welfare Dissemination Launch of the Wenlan Rekindled platform on the Alipay mini-program, with interactive tasks and digital souvenirs attracting users; over 60 technical volunteers contributed more than 2,000 hours, reducing project costs and expanding reach.

➜ Practical Results of Digital Transmission

The project has achieved dual breakthroughs in cultural protection and public dissemination.

Protection and Restoration Nearly 1,000 core volumes of the *Siku Quanshu* were digitally translated. OCR technology significantly improved ancient book processing efficiency, supporting further research and dissemination. The virtual Wenlan Pavilion fully restored architectural

appearance, achieving permanent digital preservation.

Public Dissemination and Participation Within one week, 3.5 million users engaged, with over 360,000 interactions. The digital human function had a usage rate exceeding 90 percent. Over 90 percent of users reported a deeper understanding of Wenlan Pavilion and the *Siku Quanshu*, while more than 70 percent reported enhanced cultural identity.

Social and Public Welfare Value The tech volunteer model engaged youth in cultural heritage protection, forming a lightweight and replicable "public welfare + technology" paradigm, offering transferable experience for other ancient book protection projects and promoting the living transmission of traditional culture.

➡ Future Expansion and Sustainability

The project will continue to advance through technological upgrades, expanded applications, and international dissemination.

Technological Upgrades Enhance digital humans' natural language capabilities, train domain-specific large models for ancient books, improve proofreading and translation accuracy, and optimize lightweight features for broader device accessibility.

Expanded Applications Expand digitalization to other ancient books and cultural heritage forms (e.g., opera, intangible heritage) to build an "online cultural hub"; collaborate with tourism and education sectors to develop study programs.

International Dissemination Release multilingual versions and leverage international platforms to showcase Wenlan Pavilion and the *Siku Quanshu*, enhancing the influence of Chinese culture.

Risk Response Work with copyright institutions to regulate content use; apply blockchain and encryption technologies to ensure data security and prevent copyright or privacy risks.

基于人工智能的
古籍文献大数据治理平台

世界互联网大会文化遗产
数字化案例（2025）
——物质文化遗产数字化

19

Big Data Governance Platform for Ancient Books and Literature Based on Artificial Intelligence

▶ **Applicant Institution**

Ningbo Tianyige Museum

▶ **Participating Institution**
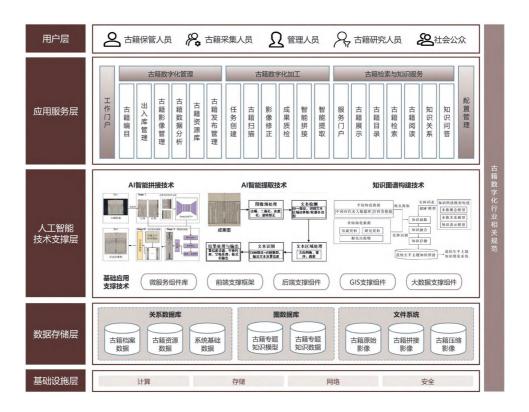
Wuhan Digital Culture Technology Co., Ltd.

This case, jointly developed by Ningbo Tianyi Pavilion Museum and Wuhan Digital Culture Technology, addresses the pain points of ancient book digitization–scattered processes, low efficiency, and limited utilization. By integrating deep learning and knowledge graph technologies, it has built a full-lifecycle big data governance platform covering physical storage and retrieval, digital acquisition, intelligent processing, and knowledge activation.

The platform is based on "full-process intelligence", supported by five-layer architecture: infrastructure, data storage, AI technology, application services, and user interface. A self-iterating multi-modal AI engine enables automated stitching of ancient book concertina-style pages, recognition of complex layouts, and extraction of text and seals, with accuracy improving as data accumulate. Business-wise, the platform establishes standardized processes and integrates multi-system functions, resolving information silos and data security risks.

➲ Standardized Control Resolves Fragmented Processes

Ancient book digitization often suffers from decentralized operations across multiple systems and inefficient and weak information connectivity. This case built an online process—from storage and retrieval, task assignment, and quality inspection to intelligent processing and release of results—while integrating cataloging and image management. This reduced the digitization cycle for a single volume of ancient books from four days to 1.5 days, significantly lowering missed or incorrect scans. Hierarchical permissions and operation log tracing further mitigate data leakage risks, addressing process fragmentation and lack of standardization.
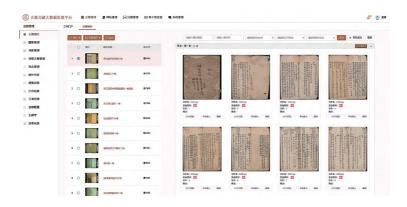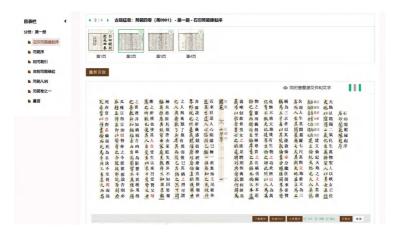
➲ AI-Driven Intelligent Processing Breaks the Efficiency Bottleneck
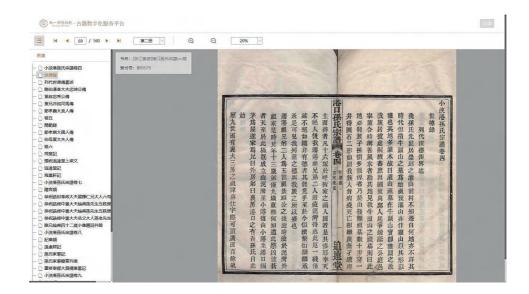
A self-iterating multi-modal AI engine, combining DeeplabV3+ image segmentation algorithms and ResNet101 feature extraction networks, automatically stitches concertina pages, trims redundant margins, and accurately recognizes complex layouts such as vertical text, double-line annotations, and variant characters. Its text and seal extraction accuracy improves with data growth. Compared with traditional manual methods, the AI system efficiency has increased

over 10 times, costs per page have dropped, and manual proofreading workloads have been significantly reduced, effectively solving the problems of low intelligence level and high labor costs.

➔ Deep Knowledge Mining Increases Utilization

A graded ancient book resource library has been built, offering 600dpi original images for academic research and compressed images freely open to the public, supporting multi-dimensional search by keyword, author, or era. Knowledge graph technology links entities such as figures, events, and seals mentioned in ancient books, creating a visual knowledge network and developing thematic services like The Life of Fan Qin. To date, the public service module has recorded 4.6 million visits, and more than 20,000 digitized volumes have been available, advancing ancient book cultural transmission from "hidden collections" to living heritage.
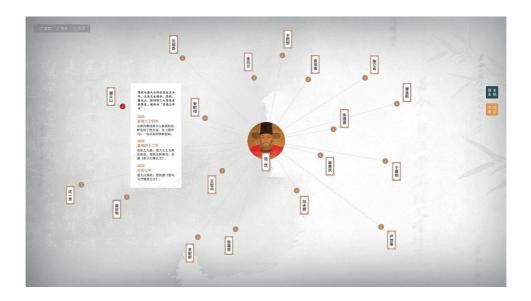
➔ Three Breakthrough Innovations Driving Industry Reform

The project achieves multiple innovations in technology, business, and model.

Technology: AI deep learning revolutionizes ancient book image processing, supported by large-scale pre-trained models and advanced image processing and computer vision, breaking the bottleneck of manual labor.

Business: A pioneering full-cycle intelligent service system for ancient book digitization integrates the entire chain from retrieval to release, reshaping industry service paradigm with standardized processes.

Model: The platform serves as a "knowledge accelerator," transforming raw data into structured knowledge networks through thematic knowledge base and intelligent retrieval services, opening new paths for utilization.

→ Transferable Experience Empowers Similar Institutions

The project refined three promotable experiences:

1. Human-AI Collaboration: AI handles repetitive tasks like stitching and extraction, while humans focus on higher-valuework, balancing efficiency and quality.

2. Sample-driven Iteration: Initial models are trained on high-quality sample libraries, iteratively upgraded with large-scale data to align R&D with real demand.

3. Lightweight Deployment: A basic version (government cloud, core functions) and an enhanced version (local deployment, knowledge graph module) suit institutions of different scales.

→ Multi-Dimensional Impact: Protection and Utilization

In physical protection, digitization reduces the frequency of physical handling, limiting damage such as torn papers or faded ink, while accurately recording deterioration details, providing visual basis for restoration. In research support, the platform has supported two provincial-level research projects, laying theoretical foundations for further studies. In industry influence, with standardized, high-precision platform capabilities, it has become a national benchmark for ancient book digitization for cultural institutions, promoting overall industry development.

In the future, the project will deepen its multi-modal AI engine, enhance recognition of cursive and seal scripts, and develop ancient book semantic correlation algorithms to build cross-lingual knowledge mapping models. It will also expand application scenarios by developing genealogy and local chronicle modules, building collaboration platforms across institutions, and optimizing lightweight deployment.

Image Database of Ancient World Civilisations
世界古代文明图像数据库

20

World Ancient Civilizations Image Database

▶ **Applicant Institution**

World Arthistory Institute (WAI), Shanghai International Studies University

▶ **Participating Institution**

Image Lab, Peking University;
Xinwei New Dimension Imagination Digital Technology (Beijing) Co., Ltd.

This case builds an innovative image digitization and database system covering world ancient civilizations, with cross-civilization perspectives and interdisciplinary integration as its core breakthroughs. Key highlights include:

1. Extending digitization from Han Dynasty images to civilizations such as ancient Egypt, ancient Greece, and ancient India, and pioneering a multi-dimensional annotation system of material, form and semantics to precisely correlate images, texts, and artifacts.

2. Establishing the "Xingxiangxue theory", grounded in the Chinese philosophy of "beings are born from non-beings", going beyond the limitations of Western image theory and providing a new perspective for cross-civilization studies.

3. Advancing international cooperation (e.g., Sino-Egyptian joint archaeology) and multidisciplinary collaboration (art history, computer technology), thereby promoting image resource sharing and integration, supporting academic research, and fostering cultural tourism and cultural dissemination.

➲ Exploration and Expansion of Image Digitization

The project originated in 1995 with Professor Zhu Qingsheng's work on digitizing Han Dynasty images. Over three decades, methods for digitizing Han images have been extended to world civilizations. Under the joint efforts of the Shanghai International Studies University World Art History Institute and other parties, the project currently focuses on the digitization and database construction of cultural heritage from ancient Egypt, ancient Greece, and ancient India (including Gandhara). The Chinese Han Dynasty Image Information Database provided a mature foundation as a full image detail identification project, supporting the compilation of *Han Hua Zong Lu (A Comprehensive Record of Han Pictorial Art*, 63 volumes published), and offering valuable technical and theoretical experience. This case addresses challenges such as fragmented global image resources, lack of systematic tools for cross-civilization research, and incompatibility between image theories across civilizations, by developing standardized digitization methods and a global research platform.

➲ Multi-Dimensional Innovative Practice System

This case forms systematic innovation at the knowledge, theory, method, and application levels.

Knowledge and Theoretical Innovation Establishing an image-word-artifact correlation database compatible with multiple civilizations through systematic research of world ancient civilization images; advancing "Xingxiangxue theory" from a Chinese ontological perspective of "beings are born from non-beings", enriching and transcending Western material-based image theory.

Methodological and Technological Innovation Promoting deep integration of art history, archaeology, and computer science; optimizing image acquisition technologies (high-precision scanning, 3D modeling, micro-trace enhancement) tailored to different materials; creating a multi-dimensional annotation system of material, form and semantics, achieving layered identification and retrieval of image details (lines, shapes, and graphic potential).

Application Innovation Using database outcomes to curate academic exhibitions (e.g., Shanghai Museum's On Top of the Pyramid: The Civilization of Ancient Egypt), promoting cultural-tourism integration; exploring image data representation methods for AI applications; building ancient civilization corpora, providing support for large-scale data analysis and visualization, breaking academic boundaries, and bridging the humanities and sciences.

《汉画总录·沂南卷》书影，著录与研究文献部分得自从研究文献数据库的检索整理，同时新发表文献补入研究文献数据库。

广西师范大学出版社，2010年至今，63卷已出版

➲ Practical Results and International Cooperation Outcomes

This case has achieved significant results in multiple fields.

Academic Outcomes The Han image database was rated excellent as a major national social science project. *Han Hua Zong Lu* based on it won the first prize of the 9th Higher Education Outstanding Scientific Research Output Award (Humanities and Social Sciences). The "Xingxiangxue theory" provides a new paradigm for image research, and its methods have been verified and expanded in the organization of world ancient civilization images.

International Cooperation Joint work with the Egyptian Supreme Council of Antiquities has completed image and inscription acquisition, translation, and research for nearly 100 ancient Egyptian painted anthropoid coffins, resulting in the first volume of *Aiji Zong Lu (Comprehensive Record of Egypt)*. Partnerships with Pakistan and Greece have enabled the organization of unpublished image materials from the Gandhara region and digitization of Greek museum collections, accumulating raw data for cross-civilization studies.

Cultural Tourism Integration Exhibitions such as Shanghai Museum's On Top of the Pyramid: The Civilization of Ancient Egypt leveraged database achievements to create high-value displays of ancient civilizations, enhancing both social and economic benefits and promoting the living transmission of cultural heritage resources.

第九届高等学校科学研究优秀成果奖
（人文社会科学）

成果名称：汉画总录
广西师范大学出版社 2021 年 12 月
主要作者：朱青生，刘冠，徐呈瑞，康兰英，凌皆兵，王清建，牛天伟，徐颖，李建，闪彬，
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杨建华，周水利，刘冠军，李晓军，杨孝军，梁勇，张玉兰，夏春华，王卫清，
何绪军，朱晓伟，钱建礼，刘云涛
奖项类别：著作论文奖
获奖等级：一等奖

教社科证字（2024）第 0040 号

中华人民共和国教育部
二〇二四年七月二十日

➲ Future Expansion and Global Civilization Dialogue Planning

This case plans to expand the database coverage through international cooperation, deepening the digitization and research application o images from ancient civilizations.

Ancient Egypt Advance digital mapping of the Saqqara Cat Temple, pyramids, and noble tombs; organize tomb chamber murals, reliefs, and artifacts; aim to complete systematic digitization of nearly one million pieces in the Egyptian Museum collection within 10–20 years, with publications in Chinese, Arabic, and English.

South Asia and Greece Follow the route of the 7th century traveler Xuanzang, jointly conduct field mapping and data acquisition of Gandhara heritage with Pakistan; cooperate with Greece to establish a multimedia exhibition hall, complete micro-trace scanning and 3D modeling of 10 museums' collections, with special focus on Greek vases.

Outcome Dissemination All digitized materials will be shared through online databases, exhibitions, and catalogues, serving academic research and public education, and supporting global dialogue and cultural integration.

AI智慧应县木塔

21

Yingxian Wooden Pagoda — Digital Twin Solution Based on Multimodal AI and 3D Vision

▶ **Applicant Institution**

Lenovo Group

▶ **Participating Institution**

Tsinghua University

This project innovatively constructs a digital twin system for ancient architecture integrating multimodal AI, 3D vision and embodied intelligence. Its core breakthroughs include:

1. Creating a 1:1, high-precision replica of the Yingxian Wooden Pagoda (a pure wooden pavilion-style structure), using spatial computing and AIGC technology to restore complex structures such as dougong brackets and mortise-and-tenon joints. Combined with seven interactive designs and 11 animated effects, it delivers a scientifically accurate and immersive "Pagoda Twin".

2. Pioneering the application of an embodied intelligent hexapod robot (robot dog) for non-contact, millimeter-level detail scanning and deformation monitoring, addressing the limitations of traditional manual surveying in terms of precision and potential damage to cultural relics.

3. Establishing a model of "industry‑academia collaboration + technological iteration + scenario expansion" enabling end-to-end support from preservation (preventive monitoring) and research (digital archiving) to activation (VR cloud tours, cultural tourism IP). This provides an exemplary paradigm of precise restoration, deep experience and sustainable operation for the digital preservation of complex ancient structures.

➲ Core Needs for Digital Preservation of the Yingxian Wooden Pagoda

As the world's oldest surviving multi-story wooden pavilion-style structure, the Yingxian Wooden Pagoda faces three major preservation and heritage transmission challenges:

1. Its structure is highly complex and endangered. The pagoda relies on over 70 types of interlocking dougong brackets and mortise-tenon joints. After nearly a millennium of exposure, it has developed a tilt, requiring interdisciplinary collaboration for restoration. Detailed recording and monitoring must be achieved under a "zero-intervention" premise.

2. Public awareness is limited. Due to its remote location and restricted access, its historical and cultural value is not widely recognized.

3. Digital presentations need to break away from homogenization. Traditional VR only displays the exterior, failing to convey the pagoda's intricate construction and historical narrative.

This project addresses these needs through digital twin technology, balancing preservation precision with public engagement, and shifting the preservation approach from remedial to preventive.

➲ Technical Architecture and Implementation Path of the Digital Twin System

The project is structured around a core pipeline of data acquisition, intelligent modeling and interactive application, developed in phases.

Technical Framework

Data Acquisition: Uses an embodied intelligent hexapod robot, drones, and 360-degree cameras to capture thousands of images of the pagoda, achieving non-contact millimeter-level detail capture.

Intelligent Modeling: Integrates AI and NeRF (Neural Radiance Fields) technology to process 15 million polygon assets. Through nearly 60,000 lines of unity programming and 4.2 GB of model rendering, a high-precision 3D model is generated within 10 hours.

Interactive Application: Leverages XR technology to design interactive scenarios such as "Dialogue with Liang Sicheng" and "Time Travel". Users can wear VR headsets to explore the pagoda's interior layer by layer, observe mortise-tenon structures, and experience its appearance across different dynasties.

Implementation Path

Foundation (2023): Launched in collaboration with Tsinghua University's School of Architecture; technical direction defined through academic seminars.

Phase 1.0 (2024): Released the Pagoda Twin, enabling simulated ascents and artistic reconstructions, and deployed a Flow of Time interactive installation.

Phase 2.0 (2025): Introduce hexapod robot dogs for deformation monitoring, create the "Guardian Pets Alliance" cultural tourism IP, and expand the technology to other ancient structures such as the Forbidden City.

➲ Technological Innovation and Preservation Model Breakthroughs

The project achieves dual breakthroughs in technology application and preservation mechanisms.

Technological Innovations

Spatial Computing and AIGC Integration: Combines AI, NeRF, and XR to create highly realistic 3D scenes, reconstructing historical events (e.g., earthquakes, artillery strikes), and delivering a multi-sensory visual and auditory immersive experience.

Embodied Intelligent Monitoring: The hexapod robot dog, equipped with a 3D vision system, autonomously adapts to complex terrain, performs millimeter-level detail scanning and deformation detection, and uses AI algorithms to automatically compare data, providing

quantitative support for preventive preservation.

Preservation Model Upgrade

From Experience-Based Judgment to Data-Driven Decisions: Establishes a visual digital archive to support preservation plan simulation and historical trace analysis.

From Closed Operations to Open Collaboration: Fosters industry-academia synergy with universities and research institutes. The project's results were selected as a representative case for the UN Internet Governance Forum, promoting technical knowledge sharing.

➲ Practical Results and Multi-Faceted Value

The project has achieved significant results in preservation, education, and dissemination.

Preservation Outcomes Transformed the pagoda's preservation model. Data processing efficiency greatly improved (10-hour 3D model generation vs. traditional labor-intensive methods), providing precise data for restoration.

Educational Impact Deployed the Flow of Time installation (displaying the pagoda's real-time age) and a "Guardian Cat Time Mailbox" at the site. Hosted professional seminars, attracting scholars and the public. Tour guides use the installations as natural teaching models.

Dissemination Reach Generated over 8,500 online reports, with coverage by authoritative media such as CCTV and the Beijing News. Social media exposure reached 230 million impressions. English-language reports brought the project to a global audience.
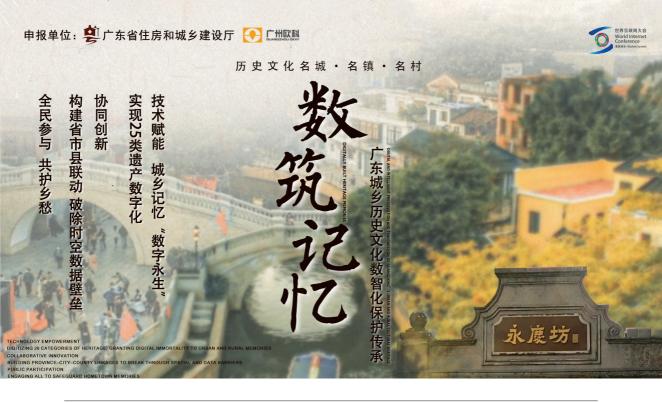
➲ Future Expansion and Sustainable Planning

The project will continue to deepen technological applications and expand scenarios.

Technology Upgrade Build a three-dimensional protection network using drones, hexapod robots and wall-climbing robots, develop specialized intelligent agents for cultural relic preservation, and achieve a collaborative preservation model of human decision-making and machine execution.

Scenario Expansion Replicate the technology for other ancient structures like the Forbidden City, explore new models of intelligent agent monitoring and immersive dissemination, and integrate into joint Tsinghua-Forbidden City research initiatives.

Risk Management Collaborate with academic institutions to ensure the accuracy of AI-restored historical scenes. Enhance equipment adaptability through tests such as extreme cold trials in Antarctica, ensuring technological stability.

历 史 文 化 名 城 · 名 镇 · 名 村

数筑记忆

DIGITALLY BUILT HERITAGE MEMORIES

广东城乡历史文化数智化保护传承

DIGITAL AND INTELLIGENT PRESERVATION AND TRANSMISSION OF GUANGDONG'S URBAN AND RURAL CULTURAL HERITAGE

技术赋能　城乡记忆 "数字永生"
实现25类遗产数字化
协同创新
构建省市县联动 破除时空数据壁垒
全民参与　共护乡愁

TECHNOLOGY EMPOWERMENT
DIGITIZING 26 CATEGORIES OF HERITAGE, GRANTING DIGITAL IMMORTALITY TO URBAN AND RURAL MEMORIES
COLLABORATIVE INNOVATION
BUILDING PROVINCE-CITY-COUNTY LINKAGES TO BREAK THROUGH SPATIAL AND DATA BARRIERS
PUBLIC PARTICIPATION
ENGAGING ALL TO SAFEGUARD HOMETOWN MEMORIES

永庆坊

22

Digital Memories: Digital-Intelligent Protection and Inheritance of Guangdong's Urban and Rural Historical Culture

▶ ## Applicant Institution

Guangzhou Okay Information Technology Co., Ltd.

This case innovatively establishes an urban and rural historical culture protection system focusing on the integration of digital and intelligent technologies and on end-to-end collaboration. Its key breakthroughs include:

1. Integrating 25 categories of historical and cultural resources across the province through unified data standards and digital-intelligent technologies, enabling dynamic "one-map" management and overcoming challenges of fragmented data and inconsistent standards.

2. Building a cross-departmental collaboration platform at the provincial, municipal, and county levels, streamlining workflows, data flows, and approval processes, thereby increasing approval efficiency by over 90% and breaking down data silos and multi-level coordination barriers.

3. Pioneering a multi-stakeholder co-governance model involving government, experts, the public, and enterprises, leveraging VR/AR and AI interactive technologies to enhance public engagement. This establishes a replicable methodology based on a "standards-first" data-and-business collaboration, and three-way integration.

➡ Digital-Intelligent Needs for Urban and Rural Historical Culture Protection

Guangdong's historical and cultural resources are characterized by their large quantity, diverse types, wide distribution, and high value. However, traditional protection models face some challenges:
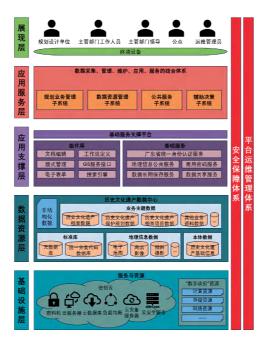
1. Fragmented data management: varying data formats and field definitions across regions, with some records still paper-based, hindering integration and utilization.

2. Inefficient cross-department coordination: involving multiple departments (e.g., housing construction, culture and tourism) and three government levels (provincial, municipal, county), leading to redundant data entry and repeated reviews.

3. Inadequate decision-making and public participation: approvals rely on manual searches, resulting in low efficiency and high error rates; limited public awareness of heritage leads to unauthorized construction and mistaken demolitions.

This case addresses these issues by leveraging digital-intelligent technologies to build a system of collection → management → analysis → decision-making, achieving precision and efficiency in preservation and inheritance.
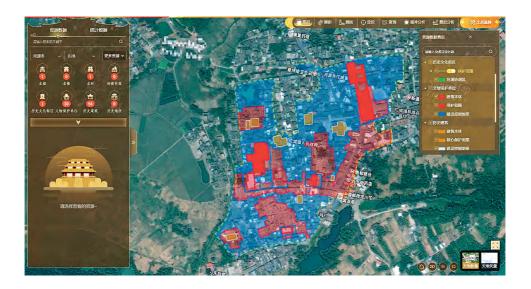
➡ Technical Framework and Implementation Path of Digital-Intelligent Protection

This case relies on technological integration and institutional innovation to progressively develop the protection system.

Technical Framework Integrates 3D laser scanning and oblique photogrammetry for high-precision

data collection, building a 3D model database; employs GIS to incorporate spatial and environmental data for visual management; utilizes big data and AI for smart monitoring, early warnings, and decision analysis, forming a closed loop of collection, management,analysis and decision-making.

Implementation Path Phase 1 (2018–2025): Conducts foundational data collection and governance, establishes unified standards, and completes a provincial historical and cultural resource survey and digital archiving, laying the groundwork for "one-map" management. Phase 2 (2021–2025): Develops a comprehensive management platform for urban and rural historical culture protection and inheritance, with subsystems for business management, data resources, and public services, enabling three-level collaboration and intelligent approval. Phase 3 (2024–2027): Pilots the platform in three cities, optimizes functionalities, gradually expands province-wide, and establishes a long-term feedback mechanism to promote multi-stakeholder participation.

➡ Innovations and Collaborative Mechanisms

This case has achieved multiple innovations in technology and management.

Technological Innovations Digital X-Ray Vision: Combines surveying and AI to accurately monitor deformation and damage of architectural heritage, enabling dynamic protection. "Intelligent Decision-Making Brain": Develops data quality inspection and spatial analysis tools, automatically generating compliance reports and multiplying approval efficiency. Homegrown Core Technologies: Adopts a domestic technological foundation to ensure platform security and autonomy.

Institutional Innovations Data Interchange: Links business and spatial data via spatial coding, standardizes cross-departmental data flow, and integrates 25 categories of heritage data for secure sharing. Multi-Stakeholder Co-Governance Ecosystem: Opens resource queries and online tours via the "Yuemingcheng" website, attracting over 1 million visits and fostering a public participation-based protection framework.

缓冲分析报告

➔ Practical Outcomes and Value Realization

The case has achieved remarkable results, delivering both economic and social benefits.

Economic Benefits The platform reduces annual workload by approximately 50,000 hours and saves about RMB 3 million in costs across departments through intelligent approvals and data sharing. Centralized development saves over RMB 10 million in software and hardware expenses. It boosts industries like planning and design and cultural creativity— e.g., one design institute shortened project cycles by 30 percent and increased annual profits by about RMB 3 million using platform data.

Social Benefits Enables precise management of 25 heritage categories and detects and addresses unauthorized construction in a timely manner. Supports scientific protection planning, such as rationally defining protected areas in historic town planning. Enhances public participation, creating a public supervision model and promoting the dissemination and education of historical culture.

➔ Future Plans and Expansion Directions

The case will continue to deepen digital-intelligent applications and expand into diverse scenarios.

Technology Upgrade Unlock the value of data elements by constructing a three-dimensional decision-making model (incorporating regulations, space and projects) and a knowledge graph of historical cultural heritage. Enhance VR/AR technologies to develop an Urban-Rural Time Machine and launch digital cultural products with Lingnan characteristics.

Scenario Expansion Integrate with emergency systems for disaster monitoring, support style protection in urban renewal, develop digital heritage research systems, and promote cultural tourism integration and rural revitalization.

Safeguarding Mechanisms Establish a protection fund, form cross-disciplinary expert teams, and deepen international cooperation. Through technological iteration and institutional refinement, achieve the following goals by 2035: one map, one collaborative channel, one multi-stakeholder ecosystem, and one set of institutional achievements.

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Digital Practices in Exhibition of Silk Road Treasures at Poly MGM Museum, Macau SAR

▶ Applicant Institution

Poly MGM Museum;

Poly Culture Communication Co., Ltd.;

School of New Media Art and Design, Beihang University

In 2024, celebrating the 75th anniversary of the founding of the People's Republic of China and the 25th anniversary of Macao's return to the motherland, Poly MGM Museum partnered with Poly Culture Communication and Beihang University, collaborating with experts from China, Italy, and France to launch the special exhibition entitled "Blue Ribbon — Exploring the Mysterious Seas and Encountering Silk Road Treasures". This exhibition celebrates the 25th anniversary of Macau's return and supports the Greater Bay Area's cultural soft power enhancement initiative. Featuring four thematic spaces and centered on 184 sets (228 pieces) of cultural relics, the exhibition introduces innovative digital practices. Custom digital content was created for four key artifacts, utilizing a 500-square-meter 8K LED screen and the "Time Collection ® Cultural Conservation Holographic Display Cabinet" to achieve an integrated physical-virtual display. A cross-institutional collaboration mechanism was established, consisting of university R&D, enterprise implementation, venue practice, and multi-stakeholder support. Breaking away from traditional static displays, the exhibition enables dynamic storytelling and multi-sensory interaction, transcending the spatial and temporal constraints of cultural communication. It synergizes cultural preservation and display, achieving remarkable results with extensive coverage by mainstream media, high visitor engagement, increased awareness of the Silk Road culture, and valuable references for similar exhibitions. It has also stimulated demand in related industries. Moving forward, the project will deepen its impact through technological refinement, commercial expansion, and industry standard development, continuing to leverage digital technology to revitalize cultural heritage and advance the digital transformation of the cultural museum sector.

Customized Digital Content for Cultural Artifacts: Building Spatio-Temporal Narrative Connections

This case focuses on 184 sets (228 pieces) of artifacts and artworks from nearly 20 institutions, selecting four key pieces including a Yuan Dynasty blue-and-white jade vase with phoenix and floral patterns and a Qing Dynasty Guangcai plate with Arabic inscriptions and figural motifs. Custom digital content was developed for each: interactive "coral erasure" via touch, high-color-rendering technology with interactive interpretation, virtual sound replication of tapping, and digitally restored dynamic scenes. These elements were woven together through digital technology to construct a multi-dimensional narrative of the Maritime Silk Road, illustrating the circulation of artifacts and cultural symbiosis, achieving the goal of making cultural relics "speak".

Integration of Technology and Exhibition Scenarios: Crafting Immersive Experiences

The case leverages a 500-square-meter 8K LED screen and the Time Collection ® Multi-Functional Cultural Conservation Holographic Display Cabinet to create a fully enveloping immersive environment. Custom display spaces were designed for physical artifacts, equipped with high-transparency low-reflection glass and intelligent lighting to meet conservation needs. Transparent OLED screens and touch-sensitive films were integrated to enable augmented reality interactions, allowing visitors to manipulate digital models. A multimodal interactive software system was developed to facilitate coordinated interpretation of digital and physical exhibits. Modular variable layouts and directional audio systems were employed in spatial design to adapt to different thematic needs, offering visitors a comprehensive sensory experience of life along the Silk Road.

Establishing a Cross-Institutional Collaborative Implementation Pathway

A synergistic mechanism was established, consisting of university R&D, enterprise implementation, venue practice, and multi-stakeholder support. Poly Culture Communication Co., Ltd provided artifact sampling tests, industry resources, and exhibit coordination; Beihang University was responsible for digital modeling, interactive system development, and tackling technical challenges; Poly MGM Museum contributed exhibition practice insights to optimize visitor experience and conservation parameters. Additionally, 16 organizations participated as co-organizers, ensuring both technological innovation and cultural- narrative accuracy and promoting the orderly implementation of digital practices.

➡ Innovating Exhibition Experience and Communication Models: Achieving Multi−Dimensional Breakthroughs

This case transforms traditional exhibitions from static display to dynamic storytelling. Digital technology endows artifacts with interactivity and narrative power, incorporating multi−sensory interactive programs and spatial narrative elements to turn visitors from "information recipients" into "historical participants". It breaks the spatial−temporal limits of cultural communication by using high−fidelity digital models to compensate for missing information in physical artifacts and authorizing the replication and dissemination of digital content to facilitate cross−border cultural exchange. It also enhances the synergy between conservation and display: compliant holographic display cabinets reduce reliance on original artifacts, minimize damage risks, and achieve the goals of prioritizing preservation and innovation in display.
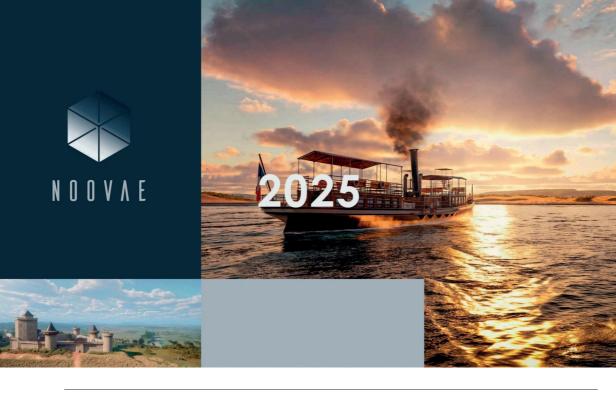
➡ Future Development Directions: Deepening the Impact of Digital Practices

The project will deepen its practices across multiple dimensions.

Technologically, by improving OLED display clarity and energy efficiency, refining interactive systems, and adding multi−language support and personalized recommendations.

Commercially, by building a "Silk Road Cultural Relics Digital Cluster", expanding into formats combining digital exhibitions with cultural creativity and education, and offering cultural museum services via relevant platforms.

In terms of industry standards, by participating in the formulation of digital exhibition standards for museums, supporting small and medium−sized museums through training and case studies, and driving the overall digital upgrading of the cultural museum sector to sustainably integrate cultural heritage with digital technology.

NOOVAE

2025

24

Deauville

▶ ## Applicant Institution

NOOVAE (France)

This case study introduces an innovative "phygital" (physical–digital) immersive urban history experience system that enables visitors to deeply perceive the historical evolution of Deauville through the integrated use of VR technology, 360° panoramic views, and QR code interactions. Its core value lies in three key breakthroughs:

1. Constructing a three-tiered experience chain of "movie + roaming + on-site QR scanning". Visitors can begin with understanding the historical context through a VR film, then navigate virtual timelines using headsets, and finally scan QR codes at physical locations to compare past and present, forming a coherent and immersive narrative.

2. Utilizing 3D scanning and Unreal Engine 5 to accurately reconstruct vanished historic buildings (e.g., grand hotels or old casinoes) and restore the city's appearance across different eras, ensuring both authenticity and immersion.

3. Enhancing public participation through low-threshold interactions (mobile QR scanning), attracting 15,000 participants within 15 days and transforming urban heritage from a static existence into a tangible historical story.

➲ Demand for Enhanced Urban Historical Communication

As an internationally renowned coastal resort, Deauville possesses a rich historical heritage. However, public awareness of its past—such as beach transformations, the city's founders, and the history of iconic architecture—remains limited. Traditional methods of historical dissemination (such as text-based introductions and static exhibitions) struggle to provide visitors with an intuitive sense of spatial and temporal changes, nor can they spark interest in exploring the "everyday heritage". This case addresses these gaps by using digital technology to create immersive experiences that not only answer visitors' questions about urban history but also encourage them to actively discover historical details through interaction.

OPENING LOST WOLDS

Allow guided tours of lost sites

Our digital models are designed with experts from the scientific community and are accessible to a wide audience thanks to video game technologies.
All our experiences can be enjoyed alone or with others, allowing for group visits to vanished sites.
We thus create a bridge between historical rigor and video gaming.

QALAAT SEMAN

Reconstruction of the Monastery of Saint Simeon in Syria

Built as early as the 5th century, after the death of Simeon, who spent more than 40 years of his life atop a column.
The site quickly became highly symbolic in Christianity and experienced several lives, from church to mosque to sanctuary where the column was preserved as a relic.
In 2018, having become an entrenched camp during the civil war, the site was hit by several missiles, which weakened it.

➲ Design and Implementation of 'Three-Stage Immersive Experience'

Centered on technological historical restoration and interactive experiential linking, the case establishes a multi-level engagement pathway:

VR Cinematic Narrative A 13-minute 360-degree VR film, based on scripts developed by historians, allows visitors wearing Oculus Quest 2 headsets to travel back 150 years and visually explore key moments and landscapes from Deauville's founding era, understanding historical context without physical movement.

Reconstruction of the Monastery of Saint Simeon in Syria
To raise awareness of this iconic landmark, we created a digital model in collaboration with the Ministry of Culture and the University of Nanterre. This model can be visited in virtual reality and on the website.

Virtual Time Travel Visitors wear VR headsets to freely stroll through six digitally reconstructed historical periods. While familiarizing themselves with the streets and buildings, they can revisit the historical scenes that moved them in the film, deepening their perception of spatial changes.

On-Site QR Code Interaction Approximately ten QR code terminals are installed throughout the city. Scanning them enables visitors to view 360° historical perspectives of their current location from decades ago on their phones. Using accelerometer sensors, they can pan around to compare past and present, facilitating immediate dialogue between history and the contemporary environment. Technically, the project leverages 3D scans of hundreds of historical elements and buildings, optimized and integrated into the Unreal Engine 5 rendering engine to ensure smooth, realistic virtual scenes and accurate restoration of lost landmarks (e.g., the 1924 Les Bains Deauville).

➲ Outcomes and Future Expansion

The project achieved significant results in a short operational period: within 15 days, over 1,000 pre-registered viewers experienced the VR film, and 15,000 people engaged with the QR code interactions. First-time VR users responded positively to the authenticity and immersion of the scenes.

Future plans aim to expand the experiential dimensions by developing a multiplayer VR mode, allowing users to collectively explore the virtual coastline, interact with 3D-scanned historical objects, and engage with virtual historical figures (e.g., the Duc de Morny, the city's founder); integrating 3D models of historical monuments into the game *Fortnite*, leveraging Unreal Engine's compatibility to enable players to explore historical settings in-game, thereby broadening the audience for historical dissemination.

Vidéo d'aperçu de l'expérience immersive

A scalable, multi-support experience
With nearly 2 million visitors expected for the Planches anniversary, it was essential to design a hybrid experience, adapted to all spectators. We have therefore, based on the same digital model, adapted it to virtual reality on headsets, smartphones via QR codes placed throughout the city, and immersive films viewable in certain dedicated spaces.

2

Exhibition and Utilization

数字 DIGITAL
LIBRARY 藏经洞 CAVE

来自中国一千多年前的
人文图书馆

01

The Digital Library Cave

▶ **Applicant Institution**

Dunhuang Academy

Most of the existing digital resource databases for cultural heritage focus on the traditional display of data itself, lacking further content mining and intelligent, interactive presentation forms. This case study integrates sutra text processing systems and metadata entry systems, utilizes knowledge graph technology to build a multi-dimensional relational database, employs artificial intelligence to assist in the intelligent recognition and proofreading of sutra text, integrates large language models to develop multilingual intelligent interpretation functions, and constructs a "Dunhuang Studies" knowledge graph based on deep learning algorithms. These concrete practices achieve multi-dimensional reorganization of academic resources, providing efficient management means for Digital Library Cave data.

"One Center, Three Clouds, One System" Architecture

The architecture of the "Digital Library Cave" database platform consists of a high-availability framework consisting of one center, three clouds and one system": namely, the Digital Dunhuang Computing Center of the Dunhuang Academy; Tencent Cloud, Huawei Cloud, and Digital Dunhuang Cloud; and the Digital Dunhuang Permanent Storage Guarantee System. Functionally, it develops capabilities for sutra image joining (conjoining fragments), splicing, sutra text extraction and revision, and sutra content entity extraction, enabling automatic mining of sutra content and Dunhuang Studies research results. Building upon common keyword search and full-text search functions, it develops single-character detection, enhanced search, and semantic search functions, providing efficient and personalized search methods to meet the diverse retrieval needs of both professional researchers and non-research users. Based on AI technology and large language models, it constructs an intelligent Q&A function, enabling generative interactive display of sutra content, which enhances user interactivity while promoting the dissemination and sharing of Dunhuang culture.

Case Innovation Practices

The platform adopts a modular development philosophy to reduce system coupling. Using Domain-Driven Design (DDD), it achieves multi-application integration and effective data sharing and exchange for Library Cave data. Through the input flow of the Digital Library Cave

精选文物

金刚经

现存「最早」的雕版印刷品

印刷于
868 年
（唐咸通九年）

总长度
500 厘米

这件《金刚经》为鸠摩罗什译本，全卷首尾完整，由7纸相连成卷，总长近500厘米。卷首第1纸为释迦牟尼在祇树给孤独园说法的版画，其余6纸为佛经，经卷的尾部书写题记"咸通九年四月十五日王玠为二亲敬造普施"。可知它印刷于唐咸通九年（868）农历四月十五，因为有准确的刊印日期，使它成为中国印刷史上的一件标志物，并被誉为"世界上最早的印本书籍"。

International Data Sharing Platform, combined with blockchain technology, the data ontology is permanently recorded and preserved with a unified timestamp. Data flows into the Digital Dunhuang Permanent Storage System after being guaranteed by the "Dual Guarantee Dual Review" process of automatic audit and manual data audit. With the guiding framework of protection, research, and promotion, and relying on the Digital Dunhuang Permanent Storage System, effective dissemination, use, preservation, and sharing of Library Cave data is achieved. Within the Digital Library Cave data management platform, high-level correlation of knowledge across various fields is realized, enabling efficient production and utilization of digital assets. With the Dunhuang Academy as the data center, Library Cave data—after undergoing processes such as precision reduction and digital watermarking—is published to the content management platform on the three Digital Library Cave clouds platforms via virtual encrypted dedicated links. After reclassification, cataloging, translation, proofreading, and secondary data review (content review, release review), the data is published to external service platforms, providing services for global users, including AI Q&A, intelligent recommendations, and efficient search functions.

➲ Continuous R&D and Iterative Updates of Platform Functions

The Digital Library Cave database platform has recorded 5,790 volumes of Dunhuang documents and sutras unearthed from the Dunhuang Library Cave, 41,952 images, recognized over 7.8 million characters of sutra content, and sorted and included 72,875 bibliographic records and 479 collation catalog entries.

In the future, the Digital Library Cave platform will continuously undergo technological innovation, developing and iteratively updating its existing functions.

Develop a Sutra Metadata System Define the structure and types of metadata through a metadata model; use data capture technology for automatic or manual metadata capture; employ standard formats and protocols to ensure metadata consistency and interoperability; utilize database technology to store metadata in relational or non-relational databases; automatically extract metadata from various data sources using metadata extraction tools.

Develop an Enhanced Assisted Research System Primarily for researchers conducting academic studies and other scenarios requiring complex processing of sutras; utilize Natural Language Processing (NLP), machine learning, and data mining technologies to improve the accuracy of document understanding and classification; support image analysis, performing text extraction from sutras through image recognition and Optical Character Recognition (OCR) technology; develop Tibetan text recognition capabilities; provide text analysis tools, such as word frequency statistics.

Develop Full-Text Search and Semantic Search Based on the established Library Cave literature lexicon and Dunhuang popular character dictionary, perform word segmentation processing on the text content within documents and build an index, enabling users to quickly locate relevant documents or records during queries.

数字中轴

小宫庙

点击任意位置开始体验

02

"Virtual Central Axis" (International Edition)

▶ **Applicant Institution**

Tencent Technology (Beijing) Co., Ltd.

▶ **Participating Institution:**

Beijing Municipal Bureau of Cultural Heritage；
Beijing Central Axis Cultural Heritage Application Office

The Beijing Central Axis is a masterpiece of ancient Chinese capital city planning and the core embodiment of the unique and magnificent layout of Beijing. The Cloud-based Central Axis mini-program, a collaboration between the Beijing Municipal Cultural Heritage Bureau and the Tencent SSV Digital Culture Laboratory, allows this World Cultural Heritage site to be fully recreated in the digital world. Now, the Cloud-based Central Axis mini-program is available in a new bilingual Chinese-English version – the Cloud-based Central Axis (International Edition), breaking down language barriers and enabling the world to understand the Beijing Central Axis up close.

➡ Digital Cultural Heritage Preservation, Activation, and Transmission

Current cultural heritage preservation and World Heritage application efforts face three core challenges:

Insufficient International Communication Effectiveness Traditional World Heritage applications rely on text and static displays, making it difficult to convey the universal value of cultural heritage into a language easily understood by the international community, resulting in low cross-cultural communication efficiency.

Insufficient Public Participation Cultural heritage preservation often relies on professional institutions, leaving the public lacking convenient channels for participation, making it hard to form a collective force for nationwide protection.

Lack of a Digital Paradigm for Physical Resources The digitization of cultural heritage often remains at the level of partial recording or display, lacking a systematic technological application framework and a sustainable model for revitalization and sharing.

To address these challenges, this case study proposes the concepts of Digital Preservation, Digital Revitalization, and Digital Transmission.

➡ Digital Preservation: Granting Cultural Heritage "Eternal Life" in the Digital World

The Cloud-based Central Axis Project/mini-program based on digital twin and gaming technology, utilizes game engines, self-developed PCG (Procedural Content Generation) technology, cloud gaming technology, etc., to create the world's first immersive interactive experience of an ultra-large-scale urban historical landscape. Building on this, a bilingual AI smart agent for real-time guided tours was launched, activating the millennial knowledge base of the Central Axis, and using digital-intelligent method to open an endless dialogue between civilizations.

➡ Digital Revitalization: Bringing Cultural Heritage to Life

A multimodal digital resource library for the Beijing Central Axis has been constructed,

establishing a 3D resource library of Central Axis buildings for immersive exploration of its historical and modern changes. The digital resources of the Beijing Central Axis are openly licensed for multi-scenario cultural and creative applications, utilizing a model including IP rights, Digital Application and public feedback to facilitate the development of digital cultural creations, physical derivatives, etc., promoting the continuous release of cultural heritage value within the creative industries.
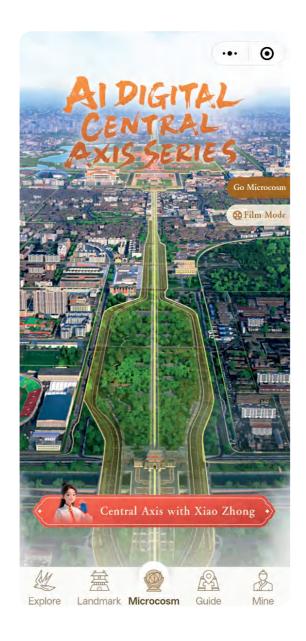
➡ Digital Transmission: Integrating Cultural Heritage into Daily Life

Innovative models have been developed for social forces to participate in cultural heritage preservation, constructing a Digital Watchman volunteer system, developing a universal Scene Code tool for cultural heritage, opening up public participation channels, and forming a public participation network for heritage preservation.

The Cloud-based Central Axis (International Edition) mini-program closely focuses on the major task of cultural innovation, dissemination, and protection of the Beijing Central Axis. It leverages three core functions – Mini Universe, Digital Watchman, and internationalization with an AI cultural heritage assistant – to explore new paths for the digital preservation and dissemination of cultural heritage, providing a reusable Chinese solution for the global cultural heritage sector.

➡ Mini Universe

Mini Universe is the world's first immersive experience product for an ultra-large-scale urban historical landscape. Using high-definition photo scanning, 3D modeling, and

PCG automatic generation technology, a cloud-based Beijing Central Axis was constructed. It employs a 4-level map mode, with 15T+ of 3D data assets, 300,000 vegetation elements, 2.2 million buildings, and complete digital reproduction of 15 heritage sites. It not only fully presents the historical regulations of ancient heritage sites like the Altar of Agriculture (Xiannongtan) and Zhengyang Gate but also allows the public, guided by hyper-realistic digital humans, to deeply participate in activities such as preparing the sacrificial ceremony for the First Farmer (Xiannong) and ringing the Yongle Bell.

➲ Digital Watchman
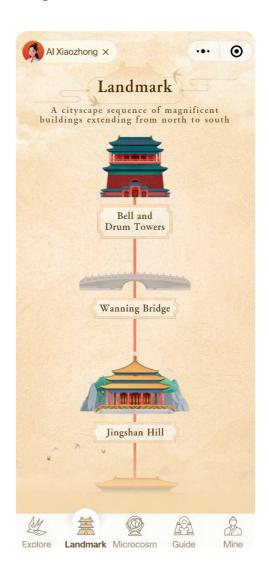
Digital Watchman Based on Tencent Map's GIS positioning, customized maps, electronic fencing, and other core capabilities, a Digital Watchman navigation and guidance system was built. It digitizes the training, assessment, and patrol processes for public participation in cultural heritage protection, enabling the general public to participate in the protection of the Beijing Central Axis heritage through scanning QR codes and taking photos. The recruitment, training, and assessment of Digital Watchman volunteers can be done online. Users can scan QR codes on heritage site boundary markers via WeChat or use the mini-program to photograph nearby buildings and cultural relics, submitting heritage inspection results. Data is transmitted in real-time to the Beijing Central Axis Heritage Monitoring Platform, forming a vertically and horizontally linked, highly efficient, and collaborative work pattern, providing a solid guarantee for cultural heritage
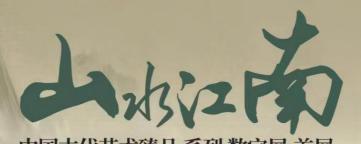
protection. To date, nearly 30,000 Digital Watchman volunteers have been trained and certified, generating over 140,000 valid heritage inspection images.

➲ Internationalization and AI Cultural Heritage Assistant

A three-layer architecture consisting of cloud data, intelligent middle platform, and a lightweight front end was constructed. The data layer integrates high-precision architectural laser point clouds and multilingual knowledge graphs; the intelligent middle platform deploys an AIGC engine and multilingual NLP processors; the front-end application is based on the WeChat mini-program framework, integrating WebGL 3D rendering engine and an adaptive bilingual interface. Millimeter-level 3D scanning and modeling were performed on 11 core buildings along the Central Axis; an AIGC dialogue model focused on cultural heritage was trained; international adaptation by establishing a specialized terminology database, achieving full bilingual UI voice/interaction; 3D models, AI assistants, and geographic guidance were seamlessly embedded into the mini-program matrix.

山水江南

中国古代艺术臻品 系列 数字展·首展
DIGITAL EXHIBITION OF ANCIENT CHINESE ART COLLECTION·FIRST EXHIBITION

展览时间:
10:15 - 17:50, 17:25后停止入馆。除国定节假日外,周二闭馆。

展览地址:
上海博物馆东馆2层数字馆(上海市浦东新区世纪大道1952号)

03

Poetic Jiangnan- An Immersive Heritage of Chinese Literati Painting

▶ **Applicant Institution**

Shanghai Museum

▶ **Participating Institution**

Shanghai Motion Magic Digital Entertainment Inc.

In the context of globalization, how to utilize modern technology to maintain and disseminate ancient Chinese art with profound cultural connotations has become a key issue urgently needing resolution in China's cultural heritage sector. The Shanghai Museum used digital technology to create an offline, object–free multimedia immersive exhibition space for ancient Chinese painting art – *the Landscapes of Jiangnan* digital exhibition. The exhibition presents the artistic essence of Jiangnan literati landscape painting in a brand new way, allowing audiences to appreciate the profound heritage and artistic charm of Jiangnan culture on both sensory and intellectual levels.

➲ Challenges in the Digitization and Exhibition of China's Ancient Art and Cultural Heritage

Aesthetic Compatibility Dilemma

Chinese ink wash painting, with its aesthetic core of differentiating black ink into five colors and ethereal artistic style, often proves difficult to accurately represent through mainstream Western digital technology systems (like VR, holography). This aesthetic disparity can lead to the unique characteristics of traditional Chinese art being diluted during digitization, making it hard to convey the profound artistic conception of the works.

Academic Communication Gap

The deep academic nature and complexity of ancient Chinese art history make it challenging to communicate comprehensively and deeply in traditional exhibitions. Especially in the field of landscape painting, static displays often struggle to present the historical context of creation, the evolution process, and the ideological connotations of the paintings and the underlying ideas of the artists.

Technological Homogenization

Many digital cultural exhibitions in the current market focus too much on visual effects and technological stimulation, neglecting the deep connotations of traditional Chinese art. Over-reliance on dazzling technological methods often results in a disconnect between the exhibition content and the technological display, lacking sufficient academic rigor and artistic depth.

➲ Innovative Practices

To address the core problems above, particularly concerning the digital representation of Chinese landscape painting art, the dynamic spatial translation of art history, and the upgrade of "living culture" transmission, the *the Landscapes of Jiangnan* digital exhibition made innovative breakthroughs. Academically, it distilled the stylistic evolution of landscape painting from the Five Dynasties to the Qing Dynasty (across five dynasties), establishing a 700-year narrative timeline. Technologically, it applied a 25K projection blending system (nearly 500 square

meters of enveloping imagery), an AIGC ink wash analysis model (extracting ink differentiation parameters) and multi-depth camera human tracking. Artistically, it presented the spatial philosophy of Paper-Ink Landscape (mirror cutting mapping "clouds/water", curved surface projection constructing "mountains"). This "tripartite approach" demonstrated significant potential in the field of digital cultural heritage display.

➡ Technical Framework

The core technical framework of *the Landscapes of Jiangnan* is based on high-end digital display technology, artificial intelligence, and deep learning models, creating an immersive art experience space.

Ultra-High-Resolution Projection Technology

Utilized multi-channel projection technology with 25K ultra-high resolution, allowing the precise presentation of details in the exhibited landscape paintings. Combined with customized mirror design and acoustic systems, the exhibition space has no physical boundaries, enabling audiences to experience a 360-degree view of the digitized landscape painting.
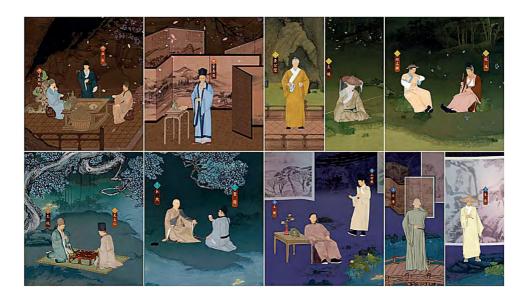
AI Intelligent Generation Technology (AIGC)

Artificial intelligence was used to analyze and generate landscape paintings from different historical periods, breaking through the challenge of representing ink wash painting in digital space. The AI's "restoration" of the paintings' content, style, color, and even textual elements ensured the artistic essence of ancient classic ink wash paintings was faithfully reproduced in the modern digital exhibition.

Digital Figures and Interactive Experiences

A major highlight of the exhibition was the use of interactive digital figures representing 16 masters of Jiangnan literati landscape painting (such as Dong Qichang, Shen Zhou, and Wen Zhengming). These "digital masters", whose appearances were recreated based on historical materials, interacted with visitors during the exhibition, guiding them to deeply understand the history of ancient Chinese art, and the creative context and artistic connotations of landscape paintings.

➜ Replicable Experience

Integration of Academia and Technology

In applying digital technology, a balance between academic rigor and artistic quality was consistently maintained, ensuring that technology serves cultural transmission and academic communication, rather than mere visual impact.

Interdisciplinary Collaboration

Collaboration across disciplines with technology companies, academic research institutions, and the cultural industry promoted the digital transformation of cultural heritage and provided important practical references for digital exhibitions in other museums.

Diversification of Cultural Experience

By integrating sensory experiences such as vision, hearing, and interaction, the exhibition helped visitors have a cultural experience and understand the essence of ancient Chinese art, enhanced the educational and popularizing aspects of the exhibition, and improved the dissemination effectiveness of ancient art and traditional culture.

China National Silk Museum
中國絲綢博物館

04

Silk Road Online Museum (SROM)

▶ **Applicant Institution**

China National Silk Museum

▶ **Participating Institution**

The British Museum;
The National Museum of Denmark;
The State Historical Museum of Russia;
Dunhuang Academy, etc.

Cultural heritage along the Silk Road is widely distributed, but varying digital standards across countries, coupled with language, policy, and technical barriers, make transnational collaboration and resource integration challenging. Traditional digital display forms are often singular, struggling to meet public demand for interactive and immersive experiences. The Silk Road Online Museum (SROM) is a virtual museum built in the cloud, initiated by the China National Silk Museum with the participation and cooperation of 44 Silk Road-related museums both in China and abroad. SROM adopts an international perspective, utilizes digital means, and targets a diverse audience, breaking through traditional institutional mechanisms and spatial-temporal barriers, overcoming the limitations of physical collections and offline spaces.

➲ Modular Architecture with a Cloud-Based Core

Based on in-depth research and examination of global museum digitization and smart museum construction cases, the China National Silk Museum divided SROM's overall architecture into three modules and one core. The Collection Module is the digital collection resource library; the Exhibition Module is the digital exhibition resource library; the Social Education Module is the digital knowledge resource library; the core is the cloud-based curation platform. On this platform, curators can select digital collection information resources, implement instant content curation and form design based on relevant digital knowledge from the resource libraries, and the finalized exhibitions can be incorporated into the digital exhibition resource library.

The cloud-based curation platform is the core of SROM. The China National Silk Museum collaborated with Hangzhou Manycore Technology Co., Ltd. to create a digital exhibition cloud design toolkit, supporting free design of 3D virtual scenes, rapid professional lighting of scenes, one-click rendering of walk-through videos, and panoramic tours of digital exhibitions. It also developed a series of libraries for dedicated display cases and pedestals, as well as decorative material libraries for carpets, wallcoverings, lighting, and glass, providing strong technical support for creating a "What You See Is What You Get" cloud-based curation platform.

➲ Conducting Professional Curation Training to Expand Platform Audience and User Experience

The China National Silk Museum prepared and conducted a series of curation training sessions. This enabled professionals from museums and universities to experience the cloud-based curation platform, establishing the first batch of professional-level users. Their feedback was used to continuously improve the platform's functions. From June 19 to 21, 2021, the China National Silk Museum held the Silk Road and Digital Curation Curator Workshop, providing over 20 participants from museums along the Silk Road with an opportunity for digital curation. The SROM project lead demonstrated the museum's display effects with examples. Subsequently, under the guidance of instructors, the participants learned about and tried out the cloud-based curation platform, completing their own cloud-based curation projects.

➲ Hosting Flagship Curation Competitions to Enhance Platform Reach and Influence

From April to June 2022, the China National Silk Museum led the organization of the Silk Road Cloud-based Curation Competition using SROM as the platform. It attracted attention and participation from over 120 domestic and international universities, more than 20 museums, and a broad designer community. Over 600 teams registered, with total participants exceeding 1,000. From November 2022 to January 2023, guided by the Zhejiang Provincial Cultural Heritage Bureau, the China National Silk Museum launched the Song Dynasty Charm Curation

Competition. A total of 402 teams with over 1,000 participants registered, including 238 university teams and 164 designer teams, covering 115 domestic and international universities, including prestigious institutions like Peking University and Tsinghua University. The featured page for the digital cultural relics library received over 60,000 views, the number of digital cultural relics collected by users reached 414,000, the platform gained 18,000 new registered users, added over 3,300 digital artifacts to the curation library, and completed the digitization of 14 exhibition hall spaces (over 10,000 square meters) from top-tier museums in Zhejiang Province. From 2023 to 2025, curation competitions will be held during the annual Silk Road Week with the themes Overland Silk Road, Maritime Silk Road, and the Silk Road in the Flourishing Tang Dynasty.

➲ Results

Since its launch in 2021, the Silk Road Online Museum (SROM) has achieved remarkable results in the field of cultural heritage digitization.

Significant Achievements in Resource Integration and International Cooperation

The SROM platform has established stable cooperation with 44 cultural institutions in 18 countries, incorporating over 5,000 high-definition digitized cultural relics. The platform's core functional system effectively supports global collaboration. The Curation SaaS platform provides cloud-based curation tools, supporting remote collaborative exhibition design; online exhibition hall design tools empower users to flexibly construct immersive virtual exhibition halls; real-time rendering technology ensures high-quality, smooth visualization of halls and exhibits; a standardized digital resource sharing mechanism, utilizing advanced technologies (like distributed storage and cross-chain protocols), effectively addresses technical barriers to sharing digital resources across institutions, platforms, and heterogeneous systems. Simultaneously, the platform's bilingual (Chinese-English) interface and intelligent guided tour system significantly enhance the international user experience, establishing a standardized platform for global digital cooperation on Silk Road cultural heritage.

Outstanding Results in Exhibition Presentation and Education

The platform's innovative cloud-based curation function realizes digitization from exhibition hall design and collection selection to exhibition presentation. This function not only lowers the professional threshold for curation but also provides a practical platform for university museum education and the training of cultural heritage professionals. The annual Silk Road Cloud-based Curation Competition has attracted 4,308 participants globally over four years, resulting in the creation of 11,216 digital exhibition proposals and the rendering of 58,294 digital exhibition images, greatly promoting the dissemination and education of Silk Road culture.

Breaking the Spatial-temporal Limitations of Traditional Exhibitions

The SROM platform uses digital technology to break down the spatial barriers of physical museums, freeing international exhibition cooperation from the constraints of high transportation costs and cumbersome loan procedures. This innovative model not only significantly reduces exhibition costs but also opens up new possibilities for planning international exhibitions, allowing more audiences to conveniently appreciate precious cultural relics from countries along the Silk Road.

Building a New Cultural Heritage Cooperation Ecosystem

The platform moves beyond traditional approaches to digital reform, emphasizing the conceptual innovation of digital cooperation. By breaking down resource barriers between museums, it enables cross-border, cross-disciplinary, cross-spatial collaboration. Nationwide cloud exhibition design competitions, held relying on the SROM platform, have not only improved the level of museum exhibition design but also deepened public understanding of Silk Road culture.

Annual Events Create Brand Influence

Integrating the Cloud-based Curation Competition with the annual Silk Road Week activities has created a cultural brand with sustained influence. This innovative model enriches the content of Silk Road Week while providing practical experience for the sustainable development of the digital museum.

05

Digital Luoyang: Digital Reconstruction of Northern Wei Luoyang Based on Immersive Multi-Dimensional Experience and Academic Co-Creation

▶ **Applicant Institution**

Harvard FAS CAMLab

▶ **Participating Institution**

Han-Wei Luoyang Ancient City Site Museum; Institute of Interactive Media, Academy of Arts & Design, Tsinghua University

Current exhibitions of ancient architecture and urban sites commonly face two types of dilemmas: one is traditional displays dominated by scale models, which, while emphasizing knowledge and precision, are often monotonous, lack interactivity, and have limited reach; the other is new media exhibitions dominated by visual imagery, which, while sensorially attractive, often resort to stacking special effects and lack historical authenticity. *Digital Luoyang* carves a third path between these two: based on rigorous research, it transforms fragmented findings into immersive, explorable virtual scenes, and enhances audience engagement and memorability through sound design and interactive mechanisms.

➜ Luoyang: Phantom City & Luoyang: Echoes Lost

The *Digital Luoyang* project consists of two complementary technical modules. *Luoyang: Phantom City* focuses on visual-spatial reconstruction, while *Luoyang: Echoes Lost* is based on sound reconstruction and narrative logic. The former uses architectural digital modeling and immersive video installations as its core to reconstruct the macro layout and key nodes of Northern Wei Luoyang; the latter employs multi-channel soundscapes to restore the city's sonic experience in different historical contexts, evoking a more emotionally resonant perception of history. Together, they form a multi-sensory narrative system, addressing issues like singular form and weak interactivity in current ancient site exhibitions.

Luoyang: Phantom City was completed through the collaboration of researchers in architectural history, art history, archaeology, literary history, and other fields from China and abroad. Grounded in systematic analysis of historical sources, it employs 3D modeling technology to reconstruct the spatial layout and core architectural complexes of the Northern Wei capital. Key structures like the Yongning Monastery Pagoda, Changhe Gate, Xuanyang Gate, Bronze Camel Avenue, Yongqiao Bridge, Lingtai Terrace, Jingming Monastery, and Qintaishangong Monastery are recreated one by one in virtual space. The Harvard CAMLab team transformed

these models into a multi-screen digital installation, stringing together memories of the city's rise and fall through four chapters — "Earth, Wind, Water and Fire" constructing an immersive, perceptible, and reflective "phantom city" through multiple audiovisual stimuli.

The project overall uses the Luoyang Research Ecosystem as its technical architecture, linking multiple dimensions such as exhibition display, interactive platforms, sound experiments, academic exchange, and publication literature to build an iterative and expandable digital cultural heritage platform. Among these, the online immersive exhibition and virtual tour sections are particularly crucial. Visitors can gradually unlock architectural nodes through puzzle games or document-based tasks, enter spaces for 360-degree exploration, and consult information on the model construction process and historical sources. In this process, the platform uses Yang Xuanzhi, the author of *A Record of Buddhist Monasteries in Luoyang*, as a guiding motif, making the
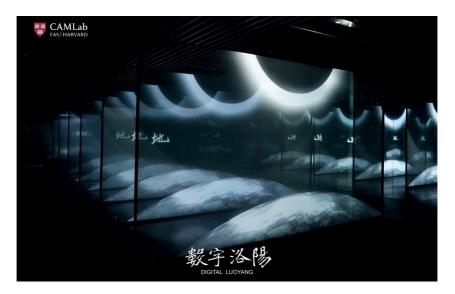
audience both observers and co-builders of memory.

Luoyang: Echoes Lost serves as an extension into the sonic dimension, constructing Luoyang's auditory landscape through multi-channel design and field recordings. From Buddhist temple bells and drums, market hustle and bustle, to the fires of war, and the sounds of contemporary archaeological sites, the audience experiences the process of Northern Wei Luoyang's progression from its zenith to its demise through the juxtaposition of sound and imagery. This sensory supplement not only enriches the narrative layers but also expands the medium possibilities for cultural heritage display.

➲ Implementation Path and Innovative Breakthroughs

The project's first phase was initiated by Harvard CAMLab, focusing research on the urban layout, religious architecture, and cultural landscape of Northern Wei Luoyang, forming an open academic platform. Through workshops, visiting scholarships, and field investigations, it attracted scholars from architectural history, art history, archaeology, Buddhist art, and digital media. In 2021, the international symposium *Multidimensional Perspectives on Northern Wei Luoyang* further solidified the project's research foundation.

The architecture team subsequently carried out 3D modeling, completing the structural logic and

scale restoration of nodes like the Yongning Monastery Pagoda, Bronze Camel Avenue, and the Changhe Gate; the design team, based on the modeling results, developed multi-screen displays, virtual tours, and sound narratives. Collaboration maintained professional division of labor, achieving a fusion of visual expression and research content.

To date, a series of outcomes have been gradually opened to the public. In 2021, the *Luoyang: Phantom City* interactive platform was launched; in 2024, the project was featured in the exhibition "Echoes of the Caravan Bell — Art of the Silk Road" displaying an immersive installation at the

Beijing Minsheng Art Museum for a broader audience. In 2025, *Digital Luoyang* will be exhibited as a highlight research-based multimedia theater project at the Museum of the Han-Wei Ancient Luoyang City Site. The exhibition combines both visual and auditory dimensions to construct virtual scenes of the Northern Wei capital, engaging in a deep dialogue with the physical site, marking an important milestone in the transition from academic research to physical space.

The innovation of *Digital Luoyang* is reflected not only in the application of technical means but also in its research-driven, interdisciplinary collaborative planning approach, exploring a systematic new paradigm for ancient city reconstruction. From its inception, the project established a collaboration mechanism involving experts from architectural history, art history, archaeology, Buddhist studies, and other fields. Under the premise of extremely scarce visual and physical material, relying on texts like *A Record of Buddhist Monasteries in Luoyang* and comparative studies of related sites, it completed the 3D modeling of iconic structures such as the Yongning Monastery Pagoda, the Changhe Gate, and the Bronze Camel Avenue. This "text-to-image" approach fills

the gap left by traditional site-based projects where "there is nothing physical to build", providing reliable academic support for digital reconstruction.

On one hand, the project creates an immersive artistic space through imagery and multi-screen installations, allowing the audience to feel the historical instant of a city's construction, flourishing, and demise; on the other hand, it builds an online platform, incorporating game mechanics, task unlocking, and interactive narrative methods to enhance audience exploration and participation. By gradually unlocking architectural nodes and reading annotated materials, users become not just receivers of historical information but also participants in the reconstruction of urban memory in the role of "weavers", achieving a combination of knowledge translation and public education.

Furthermore, the soundscape constructed by *Luoyang: Echoes Lost* breaks the convention of the vision-dominated site display, infusing the immersive historical narrative with temporal nature and emotional tension, enabling the audience to experience the vicissitudes of a city through the interplay of sight and sound.

生命艺术——马王堆汉代文化沉浸式数字大展
THE ART OF LIFE: Multimedia Exhibition of Mawangdui Han Culture

THE ART OF LIFE

2024 6/8 ▶ 2025 5/18

湖南博物院一层特展一厅

HUNAN MUSEUM 湖南博物院
中国数字图书馆 DIGITAL LIBRARY OF CHINA
CAMLab FAS | HARVARD

06

The Art of Life - Mawangdui Han Dynasty Culture Immersive Digital Exhibition

▶ **Applicant Institution**

Hunan Museum

▶ **Participating Institution**

Harvard FAS CAMLab; China Digital Library

The Mawangdui Han Tombs, representing the highly advanced artistic and philosophical achievements of early Chinese civilization, have long been a focus of global archaeological and historical scholarship. The Art of Life　— Mawangdui Han Dynasty Culture Immersive Art Exhibition is one of the largest single-investment digital exhibitions in China's cultural heritage and museum sector, and the first digital exhibition globally on the theme of the Mawangdui Han Tombs. It attempts to establish a new paradigm for cultural heritage display with global influence across multiple dimensions including academic rigor, experimental approach, and public engagement.

➡ Highly Integrated Narrative Structure and Spatial Design

Traditional exhibitions often rely on static, archival presentations, making it difficult to engage audiences in the digital age, especially younger generations; a vast amount of specialized research from fields like archaeology, history, and art history lacks effective translation mechanisms, leading to high barriers to public understanding and limited acceptance; many digital exhibitions overemphasize visual sensory stimulation, neglecting intellectual depth and cultural logic, easily falling into the trap of showing off technique rather than effective communication.

Unlike other digital exhibitions that focus heavily on visual experiences, the Art of Life exhibition practices a high degree of integration between intellectual depth, edutainment, narrative structure, and spatial design. It breaks the stereotype of new media exhibitions prioritizing sensory entertainment, allowing cutting-edge digital technology, artistic expression, and academic foundation to uniformly serve public education.

Faced with highly archival, academic, and static physical materials and documentation, the exhibition's creative team sought to transform them into a cultural experience with public educational value and contemporary aesthetic appeal. Through three thematic sections—Space-Time, Yin-Yang, and Life — the exhibition progressively reveals the grand imagination and artistic expression of the universe and life in ancient China, as embodied by the Mawangdui Han Tombs. Each section not only demonstrates the fusion of visuals and space but also strictly adheres to the original structure of the artifacts, their iconographic systems, and historical context, ensuring a rigorous correspondence between artistic reinterpretation and academic interpretation.

This case study focuses on the intersection of digital interpretation of cultural heritage and public education dissemination, aiming to address issues such as insufficient translation of academic results in traditional cultural displays, limited public participation, and singular forms of communication. The project integrates academic research, digital technology, and artistic expression to explore effective pathways for transforming ancient Chinese culture within a contemporary context. As an exhibition open to global audiences of all ages, The Art of Life not only maintains the rigor of cultural relic display but also enhances public understanding and cultural perception through immersive experiences, providing a practical sample worthy of reference for the creative transformation and innovative development of outstanding traditional Chinese culture in the new era.

➡ Three-Act Light and Shadow Performance

The Art of Life exhibition uses cutting-edge display technology to facilitate the presentation of the spiritual connotation of cultural heritage. The exhibition features a three-act light and shadow performance set within a 10-meter-high dark space.

The first exhibition area, Space-Time, is a multi-layered imagery space utilizing 3D projection

and mirrored floors. Employing technologies such as digital artifact restoration, naked-eye 3D, and 3D particle rendering, it presents the tomb chamber structure of the Mawangdui Han Tombs, exquisite burial objects, divinatory diagrams, and bamboo slip texts through four acts of imagery: Construction, Vessels, Dao, and Realm.

The second exhibition area, Yin-Yang, uses vertical projection in a mirrored space, connecting the decorative patterns on the nested coffins—which reflect the dispersal, germination, intertwining, and crystallization of the vital forces Yin and Qi—through 16 suspended semi-

transparent projection screens, each nearly 7.5 meters tall, creating a drama of life. Light and shadow refract and nest layer upon layer.
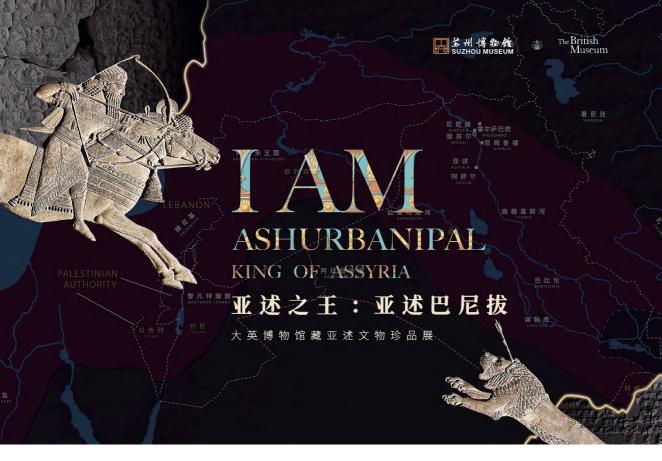
At the exhibition's climax, the third area, Life, utilizes 3D modeling, generative art, and recordings of ancient musical instrument sounds. Within a giant 15-meter diameter inclined open dome

screen, it presents four acts of digital imagery, accompanied by the sounds of Han Dynasty instruments like bianzhong (chime bells) and bianqing (stone chimes), creating a powerful and imposing atmosphere.

The first and second exhibition areas use 4K projection mapping and ultra-short-throw optical path design to create an immersive imagery field. The third area employs the world's first museum-specific LED transparent immersive dome screen technology, achieving synchronized sound and image penetration, providing audiences with a more realistic immersive experience. All exhibition halls use lightweight, safe, high-color-rendering materials to ensure the stability of the display structures and the accurate color reproduction of the exhibits.

苏州博物馆 SUZHOU MUSEUM   The British Museum

I AM
ASHURBANIPAL
KING OF ASSYRIA
亚述之王：亚述巴尼拔
大英博物馆藏亚述文物珍品展

07

Interactive Display and Dissemination of the "I am Ashurbanipal, King of Assyria" Special Exhibition

▶ **Applicant Institution**

Suzhou Museum

▶ **Participating Institution:**

The British Museum

"I am Ashurbanipal, King of Assyria" is the third exhibition in the cooperation series between the Suzhou Museum and the British Museum's History of the World's Civilizations. To break down the barriers for Chinese audiences towards this unfamiliar theme and achieve two-way communication, the exhibition innovatively adopted an interactive experience system. It utilized 3D mapping animation technology to restore the original colors of artifacts, and employed artifact scanning and animation production techniques to present content analysis animations of historical scenes.

➲ Triple Challenge of Cognitive Barriers, Display Methods, Technical Adaptation, and Problem Focus

This exhibition faced three challenges. The theme of Assyria presented high cognitive barriers; the public lacked systematic understanding of its historical context and artistic features, making independent displays seem obscure. Traditional exhibition methods relied on one-way communication, making it difficult to spark audience interest in exploring an unfamiliar topic, resulting in communication obstacles characterized by a difficult introduction to the theme and weak interaction. Technical adaptation was challenging; Assyrian clay relief artifacts, due to high absorbency and rough surfaces, caused 3D mapping projections to be easily interfered with by texture, leading to calibration deviations. Furthermore, the complex spectra of painted pigments required non-contact restoration to balance scanning accuracy with cultural relic protection. Interactive installations also needed to overcome equipment coordination issues for motion sensing and real-time projection linkage.

During its development, this case study primarily focused on the following problems.

The Challenge of Restoring the Original Appearance of Faded/Damaged Paintings.

Painted decorations on clay tablets from the Neo-Assyrian period often suffer from faded colors, local damage, or blurred information due to age. Relying solely on the naked eye or photographs cannot restore the original color saturation and pattern integrity. Technology was used to analyze and detect the original pigment composition and color data, combined with precise 3D mapping projection, to present vivid colors on artifacts like the Sebetti Gods, Palace Carpet, and

Ashurbanipal's Palace, filling the information gap between the current state and the historical original, making faded patterns and blurred colors "reappear."

The Challenge of Integrating and Visualizing Multi-Source Archaeological Information.

Restoring painted clay tablets requires integrating archaeological excavation data, documentary records, and scientific testing results, but this information is scattered across reports and atlases, making systematic presentation difficult. Technology addressed this through data fusion, transforming fragmented information into visual projection content, solving the problem of incomplete restoration caused by disjointed multi-source information, and ensuring scientifically sound and complete results.

The Gap Between Artifact "Readability" and Public Cognition.

Lacking professional knowledge, the average viewer finds it difficult to interpret the connotation and artistic value of patterns from faded and damaged tablets. Technology lowered the barrier to understanding by accurately restoring colors and patterns, combined with designs like local magnification, detailed explanatory projections (e.g., for The Battle of Til-Tuba, Garden Party), and physical interaction (e.g., motion-sensing for The Lion Hunt, The Assyrian King and His Friends, and graffiti interaction for An Assyrian Adventure), making historical information easier to perceive and accept.

➲ Achieving Non-Contact Precision Restoration Through Projection

Traditional restoration and display methods can easily damage artifacts, struggle to reproduce three-dimensional texture, rely heavily on restorer experience, and have significant error margins. This case study achieved virtual restoration through projection, which is completely non-contact throughout the process, avoiding interference with the tablet's structure and original

remains; through 3D modeling and real-time calibration, the projection precisely conforms to the tablet's undulations, supports dynamic animations (e.g., simulating the drawing process), and enables three-dimensional dynamic presentation; through spectral analysis, digitization of literature, and other means, color data was converted into precise parameters, combined with ambient light compensation algorithms to minimize color deviation.

Technically, the framework first addressed damaged areas by using archaeological literature and AI image in painting algorithms to complete lines or patterns; it restored the original color values for each painted section, generating a digital painted layer with complete color information. Next, it established a spatial coordinate mapping relationship between the projection equipment and the tablet through infrared marker points or visual recognition algorithms; a real-time calibration

mechanism was introduced to ensure the projected patterns perfectly aligned with the tablet's surface texture and pattern positions. Simultaneously, the restored painted layers and dynamic animations were bound to a 3D mesh model, generating "texture-mapped animations" adapted to the three-dimensional surface, avoiding stretching on protrusions and compression in depressions.

➡ Iterative Dynamic Updates and Collaborative Symbiosis

This case study stores the restored content in a digital system, allowing for real-time parameter adjustments based on new archaeological discoveries, keeping pace with the latest research. It replaces high-frequency display of the artifact itself with virtual display, meeting public cognitive needs while reducing wear and tear on the artifacts, achieving protection and display empowerment.

Technologically, it employs hardware collaborative control. The Lion Hunt and The Assyrian King and His Friends use 7150LM engineering projectors and infrared sensing devices for interaction based on human movement; the An Assyrian Adventure graffiti interaction uses 4x 3050LM 4K engineering projectors, 3x 21.5-inch touch all-in-one PCs, and audio equipment to create sunny/rainy atmospheres through changes in image and sound during the coloring interaction. Back end visitor interaction statistics enable the collection and aggregation of exhibition interaction data for footfall analysis; artifacts like the Sebetti Gods, Palace Carpet, and Ashurbanipal's Palace use 5500LM engineering projectors with 0.81–0.88 short-throw lenses, large lens shift, high zoom ratios, and DLP technology, offering advantages like high brightness, accurate color, fast response, and strong durability. Garden Party, The Lion Hunt, and The Battle of Til-Tuba use an 86-inch commercial display and a 7150LM engineering projector respectively, combining animation and artifacts to show detailed information from tablets not present at the exhibition. Ashurbanipal's Library uses 3x 7150LM engineering projectors combined to form a curved screen. Through the coordination of hardware with supporting video playback systems and synchronous playback systems, the linkage of data,models and projection is achieved, balancing display effects with cultural relic protection.

Digital First National Congress of the CPC
★
A Virtual Sanctuary for the Chinese Communists

数字一大
中国共产党人的精神家园
出　品：中国共产党第一次全国代表大会纪念馆　　联合出品：中国联合网络通信有限公司

08

Digital Service Matrix of the First National Congress of the CPC

▶ **Applicant Organization:**

The Memorial Hall of the First National Congress of the Communist Party of China

▶ **Participating Institution:**

China Unicom (Shanghai) Industrial Internet Co., Ltd.

The field of revolutionary memorials currently faces pain points such as limited offline exhibition space, restrictions on displayed artifacts, capacity limits on visitor numbers, insufficiently diverse methods for disseminating revolutionary culture, and outdated presentation formats for revolutionary educational content. In 2022, the Memorial Hall of the First National Congress of the CPC partnered with enterprises and academic institutions to create a metaverse service matrix for the "Digital First National Congress of the CPC　— The Spiritual Home of Chinese Communists", further promoting the living transmission, display, and dissemination of revolutionary artifacts and Communist/CPC culture.

➔ ## Creating the "Digital First National Congress of the CPC" App, Building a New Vehicle for CPC Culture Transmission

The project utilizes digital twin technology to create high-precision models of three national-level protected buildings under the memorial's management—the Site of the First National Congress of the CPC, the Bowen Girls School, and the Former Residence of Zhou Enlai (Shanghai)—as well as precious collection items and documents like *The Manifesto of the Communist*, achieving a digital presentation of historical architecture that transcends time and space. In the Era of Zeal

section, audiences can tour the digital twins of the Site of the First National Congress, the Bowen Girls School, and the Former Residence of Zhou Enlai (Shanghai) in the online world, learning about the great revolutionary stories behind them through interaction.

The project also employs digital native technology to create metaverse exhibitions. In the Mountains and Seas Gleam Together section, seven major thematic revolutionary artifacts were unveiled collectively for the first time on Mission Island, where revolutionary artifacts like *The Manifesto of the Communist* and *New Youth* (also known as *La Jeunesse*) can be viewed up close and their pages can be virtually turned. Thirty major historical art pieces were exhibited in the Hilltop Art Gallery, creating an immersive artifact and art exhibition that transcends time and space.

The Digital First National Congress of the CPC App also created two native meeting scenarios — the Mysterious Meeting Room and the Thousand-Person Meeting Hall — offering premium Party lectures tailored to different groups like Party members and youth, enabling the online extension of educational services from Communist/CPC culture sites.

➲ VR Journey to the CPC's Beginnings: An Immersive CPC Culture Experience for the Digital Age

The Memorial launched the nation's first large-scale multi-person VR immersive CPC culture experience—Digital First National Congress · Journey of the Initial Heart. The project utilizes cutting-edge LBE VR, digital twin, 5G+XR network-media integration, and digital virtual guide technologies to efficiently reuse CPC culture "digital assets". Using Shanghai's role as the birthplace of the CPC's founding original intention and the nurturing ground of the great founding spirit of the Party as its core content, it allows audiences to travel back to early 20th-century Shanghai and witness the convening of the First National Congress of the CPC.
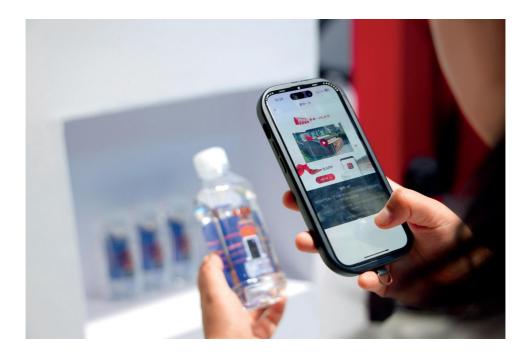
Digital First National Congress · Journey of the Initial Heart received its filing number (the Dragon Label) from the China National Film Administration on June 23, 2025, becoming Shanghai's first virtual reality film project to be officially filed, actively exploring new paths for the digital dissemination and promotion of revolutionary artifacts.

➲ Developing the Mini-Program for the Digital First National Congress of the CPC, Enabling Digital Display of CPC Culture

The mini-program for the Digital First National Congress of the CPC integrates smart tours, AR scanning, XR exhibition viewing, digital collectibles, and more. It features sections like an Activity Center, Place of the Initial Heart Tour Island, AR Experience Island, Cloud Exhibition Island, and a 3D Theme Island, delivering a new interactive experience for CPC culture visits.

The Place of the Initial Heart tour allows visitors, embodied as Q-version character "Shen Xiaoyi," to shuttle between three revolutionary historical buildings — the Site of the First National Congress, the Former Residence of Zhou Enlai (Shanghai), and the Bowen Girls School— to learn knowledge and participate in challenges. Entering the AR Experience Island, visitors can easily scan a water bottle or a 12 Li house number plate to listen to the story behind 12 Li, experiencing the integrated interaction of history and reality, online and offline. also scan offline points like the house number of 106 Wangzhi Road at the Memorial Hall and the Former Residence of Zhou Enlai (Shanghai) to learn more historical stories behind the protected buildings. Cloud Exhibition Island brings precious revolutionary artifacts and red art works online, allowing visitors to appreciate the charm of items like *The Manifesto of the Communist* up close. Characteristic theme islands create a vibrant digital community through lightweight interactive experiences; visitors can also collect digital collectibles by completing tasks, enhancing their sense of acquisition and experience through collection and interaction.

➲ Multiple Innovations in Technology and Models, Achieving Living Transmission and Active Utilization of Cultural Heritage

The Memorial Hall has actively explored the application of the latest technologies in its digital transformation. In the backend of the app/mini-program for the Digital First National Congress of the CPC, the Computing-Network Brain, through its integrated computing-network orchestration and scheduling center, interfaces with computing power and network resource

management systems, fully monitoring the overall operation of the metaverse app. This further enhances user experience and supports 20,000 simultaneous online users. AI intelligent cloud rendering replaces client-side rendering; a twin-base cloud rendering management module built on real-time image rendering and real-time voice generation technologies automatically adjusts rendering precision based on task characteristics and scene classification, optimizing rendering efficiency and realizing the nation's first thousand-person same-screen online CPC metaverse meeting room. In the construction of the Digital First National Congress · Journey of the Initial Heart VR experience, mixed-channel wireless streaming technology was employed for the first time, upgrading the 5G-A cloud solution. This addressed the pain points and difficulties of limited channels and supported device numbers in large-scale VR, delivering high-definition, high-standard visual quality content.

The support of technology has not only enabled the memorial's services to break through previous limitations in terms of audience numbers and geographical reach, innovating Party building models and enriching the forms of CPC culture experience, but it also represents a new expression and experience of applying new technology to fulfill the original aspiration and mission regarding cultural heritage protection and transmission, truly bringing cultural relics to life. It is also a successful exploration of the deep integration of digital technology and CPC cultural tourism.

CANAL WONDERLAND

运河奇境

THE IMMERSIVE VR ODYSSEY

VR 大空间沉浸式体验探索展

09

Canal Wonderland: A Large-Scale Immersive VR Odyssey

▶ **Applicant Institution**

China Grand Canal Museum

As the world's earliest excavated, longest-flowing, and largest-scale canal, the Grand Canal faces three major challenges in cultural dissemination: the immense spatial-temporal span of this linear cultural heritage site creates high cognitive barriers due to its specialized knowledge, and younger generations' methods of engaging with traditional culture are changing. To address this, the China Grand Canal Museum in Yangzhou, in collaboration with a technical team, created China's first museum-original gamified VR large-scale project, "Canal Wonderland —The Immersive VR Odyssey". This allows audiences to deeply perceive the Grand Canal's spiritual core as a "flowing culture" through free movement and real-time interaction.

➡ Transformation from Academic Research to Experience Design

The project established a closed-loop system of Academic Research —— Creative Transformation —— Experience Design, meticulously selecting historical scenes related to the canal for digital restoration. In the scene of the Battle of Suiyang, it recreates the incident where Zhang Xun and Xu Yuan held off 100,000 rebel troops with 7,000 weary soldiers. The Nanwang Water Distribution Hub scene, based on historical documents, replicates the architectural layout of the Daicun Dam and the Water Distribution Dragon King Temple. Visitors can operate the

sluice gates themselves, experiencing the hydraulic ingenuity behind the system, which directs 70 percent of the water north and 30 percent south.

In the Qu You Ge (Pavilion of Melody and Seclusion) virtual space, digital models of ancient canal bridges are built based on physical prototypes. Collection artifacts like the Ming Dynasty cloisonné interlocking lotus pattern vase and the cloisonné enamel furnace of the Jingtai period of the Qing Dynasty are naturally integrated into the scene. Visitors can observe artifact details panoramically, breaking through the viewing limitations of physical display cases.

➡ Emotional Bond Between Canal Culture and Audience Resonance

An original IP character, Little River Spirit Anlan, was created based on Gongfu, a mythical flood-controlling beast from the traditional legend of the Dragon King's nine sons. The design blends natural water hues with elements inspired by historical artifacts. The main color palette is extracted from the water colors of different sections of the canal. The head pattern draws inspiration from the Ming Dynasty cloisonné interlocking lotus motif, while the abdominal scales reference the Xuande mark cloisonné interlocking lotus pattern. Anlan retains the mythological traits of swallowing rivers and spitting rain, while its rounded lines and lively expression give it a cute appearance. It creates an emotional bond connecting the audience with history, running through the entire experience and guiding the narrative progression.

➡ Integrated Innovation of LBE Virtual Reality and Gamified Interaction

The project employs 8K resolution to present virtual scenes, making every engraving mark on ancient bridge reliefs and the texture of grain ship planks clearly visible. It is equipped with a 66-lens panoramic motion capture system that captures audience movements at 180 frames per second. Combined with VR devices featuring a 105-degree ultra-wide field of view, it achieves sub-second real-time response, ensuring action synchronization during interaction.

Based on LBE (Location-Based Entertainment) spatial positioning technology, the project constructs virtual scenes within a 350-square-meter physical space, supporting dozens of people walking simultaneously without path conflicts. The system uses positioning and boundary algorithms to remind audiences in real-time to avoid physical obstacles, allowing them to explore the maximum boundaries of the virtual scene.

The project adopts a dual-mode architecture with an immersive storyline and exploration, setting multiple interactive nodes: In the map scene, audiences use hand gestures to rotate a dial, turning back time to the historical grandeur when King Wu of Wu excavated the Hangou Canal, while simultaneously seeing the changing scenery of the four seasons. In the Battle of Suiyang, transformed into defending soldiers, they can pick up weapons from the ground and cast spells to suspend enemy arrows mid-air. In the Nanwang water distribution segment, they push virtual sluice gates to regulate water flow, observe the impact of water levels on grain ship passage, and understand the scientific principles of hydraulic engineering. These interactions are not merely entertainment but transform historical knowledge into operable experiential segments, achieving the educational effect of learning through play.

The project breaks down the 25-minute experience into 5 independent scene units. Each unit can be combined independently, adaptable to different spaces like museum exhibition halls or scenic area experience centers. Technical interfaces reserve API channels, supporting data exchange with external systems. This design provides a replicable solution for the digital display of linear cultural heritage, attracting numerous cultural and tourism institutions along the canal for inspection and cooperation.

何以文明

|中华文明探源工程成果数字艺术大展|

指导单位：中央广播电视总台、国家文物局

主办单位：央视网、国家文物局新闻中心
中央广播电视总台"央博"数字文化艺术博物馆

10

Civilization in Archaeology — A Digital Art Exhibition Exploring the Origins of Chinese Civilization

▶ **Applicant Institution**

YangBo Digital Media Technology Co., Ltd.

Civilization in Archaeology　— A Digital Art Exhibition Exploring the Origins of Chinese Civilization is an innovative project by China Media Group to implement the national cultural digitalization strategy and advance the building of China into a socialist country with thriving cultural strength. This case aims to utilize a wealth of new technological means, such as high−precision 3D virtual modeling, immersive digital interactive spaces, and an open cloud rendering engine architecture, to allow the public to more intuitively and vividly experience China's five thousand years of history and culture, thereby helping cultural relics and art better integrate into people's daily lives.

➲ A Highly Engaging, Interactive, and Exploratory Platform for Discovering Ancient Civilization Sites

This case employs digital technology to immersively recreate authentic scenes from 5,000 years ago at ten key sites: Hongshan, Liangzhu, Lingjiatan, Shijiahe, Jiaojia, Taosi, Shimao, Erlitou, Yinxu, and Sanxingdui. It constructs a spatiotemporal framework spanning from approximately 6,000 to 3,500 years ago, connecting fragments of civilization located in different parts of the country. Using 100 representative unearthed artifacts to recreate ancient craftsmanship, it builds an interactive platform for exploring archaeological sites that offers good aesthetic appeal, high interactivity, and strong explorability.

Civilization in Archaeology was launched in November 2022. After conducting in-depth learning and research on the ten key sites, the core team for the first phase of the overall digital art exhibition was assembled. Planning for the online IP exhibition and scene development for each site began in December 2022. From the outset, the team, under the guidance of the National Cultural Heritage Administration and archaeological experts, completed the overall curation of Civilization in Archaeology, and directed the team from Alibaba Cloud Intelligent Design Center in the overall design and implementation. After the project launched, the project team, alongside the archaeological expert team, guided the designers in completing the construction of multi-layered digital assets such as scene assets, character assets, and music and sound effect

assets, integrating them into the UE5 engine. Combined with front-end UI design, the overall front-end asset construction was completed. During the development phase, the team held regular weekly review meetings to conduct walkthroughs covering assets, user experience, and public sentiment, controlling the project implementation progress and completing multiple rounds of testing and optimization.

As of now, the digital art exhibitions for the ten sites involved have been completed and launched.

➲ Project Results

Civilization in Archaeology is a big-scale art exhibition created by integrating a series of digital design technologies including 3D spatial design, digital virtual human design, cultural relic digital restoration, and intelligent generation of digital assets. Visitors can access the exhibition anytime, anywhere through multiple terminals (PC, mobile, VR). They can use digital avatars to "teleport" instantly, traverse the past and the present, find themselves on Civilization in Archaeology Island, stroll through the sites described as "a sky full of stars", trace the origins of ten Chinese civilization sanctuaries, complete an unforgettable journey to find their roots, and personally experience the grandeur and glory of how Chinese civilization developed over 5000 years.

The project resulted in multiple economic benefits. Firstly, the case uses virtual reality technology to create immersive digital interactive spaces by restoring authentic scenes from the sites, and to upgrade the display methods. This allows more people to gain a preliminary understanding and interest in the sites and civilizations through online viewing, generates public interest in on-site visits, and provides new ideas for local cultural tourism and cooperation between museums and the cultural tourism sector.

Secondly, breaking through the traditional display methods in the museums, this case provides museums with immersive display extensions by integrating virtual reality and augmented reality

technologies, which not only upgraded the content volume and freshness of museums but also effectively attracted visits for cultural tourism. The exhibition creatively applies digital human guides, embedded interactive challenges, 3D artifacts, and other innovative digital products to extend the structure of the museum exhibition experience, upgrades the display methods, and provides the industry with a brand-new case and solution for holding digital exhibitions in the 3D world.

Thirdly, the case uses cloud rendering technology to render 3D scenes on remote servers. Users can access each site scene via an app or on a PC with the aid of high-speed internet connections. The server can execute corresponding rendering tasks based on user commands, and the rendered images will be transmitted back to the user's terminal for display. This technology significantly reduces the storage pressure on the user's devices, broadens application scenarios, and allows more users to experience the exhibition easily.

Finally, the case creates a linkable IP and launches IP derivative businesses such as study tours linked to the sites. It organizes "Civilization in Archaeology" Youth Archaeological Teams at sites like the Liangzhu Archaeological Site Park, cooperating with tourism groups to boost

local cultural, catering, and accommodation consumption, thus expanding opportunities for local cultural tourism businesses.

In terms of social benefits, firstly, it enhances the accessibility of cultural services. Through immersive and digital means, the exhibition presents the development process of the origins of Chinese civilization, along with historical scenes and inventions from various periods, allowing the public to more intuitively and vividly experience China's five thousand years of history and culture, helping cultural relics and art better integrate into people's daily lives and reach a global audience.

Secondly, it aids cultural education. This case presents specialized academic knowledge through immersive scenes and rich interactive methods, visualizing archaeological achievements and the characteristics of civilizations. It combines education with entertainment, allowing more visitors to quickly understand the archaeological achievements of related civilizations through simple operations in a short time, aiding cultural dissemination and achieving broader social education. Simultaneously, Yangbo has also licensed some digital assets from the exhibition to universities,

enriching and extending the exhibition's content through university-enterprise cooperation and co-creation. This allows university students to design practical scenarios, apply their knowledge to real projects, learn by doing, drives universities to enhance students' digital resource development skills, and promotes the development of the cultural design industry.

Finally, it increases the global dissemination and influence of Chinese civilization, enhancing cultural confidence and social identity. On June 29, 2023, the opening ceremony of the Civilization in Archaeology Global Tour · UN Special Exhibition was held at the UN Headquarters in New York. Since its launch, the exhibition has attracted attention from various sectors at home and abroad. To date, touring exhibitions have been held at many renowned venues and in multiple countries and regions, including the UN Headquarters in New York, the Palais des Nations in Geneva, the UK, Egypt, Peru, and Hong Kong SAR of China. This case has strengthened the global dissemination and influence of Chinese history, contributing wisdom and strength to promoting mutual understanding and friendship among the people of all countries and regions, and advancing the building of a community with a shared future for mankind.

11

ORA Sphere Applied for Cultural Heritage Digitization

▶ ## Applicant Institution

Atmosphère (France)

In traditional exhibition models, artifact display often relies on static presentations, resulting in poor audience interaction and difficulty in deeply perceiving the historical context behind the artifacts. The limitations of physical displays also restrict the breadth and depth of cultural dissemination. This case study presents the ORA Sphere, an original, interactive immersive spherical projection system. Through the ORA Sphere, significant scenes and events from various historical eras can be visually displayed, enhancing the interactivity and immersion of the viewing experience.

➲ Successful Practice of the Educational Project "Time Sphere"

The ORA Sphere is already in use in numerous museums, libraries, and educational institutions worldwide. One of its most representative applications is the Time Sphere, developed for the French Ministry of Education's National History Program. The Time Sphere is built around a series of interactive timelines. Teachers can use the Time Sphere to conduct various history teaching activities.

A continuous interactive ribbon zone will be displayed around the equator of the sphere. Users can select a specific era and explore related digital assets — including images, videos, and audio recordings. By clicking on specific items, users can access their content simultaneously on the sphere and a tablet screen, creating a truly immersive and informative experience. Upon selection, corresponding animations will be displayed either on the entire sphere or on zoomed-in areas on both sides of the sphere. Within minutes, students can travel back and forth through time and space, intuitively understanding major historical developments.

In addition to playing audio, video, and image materials, teachers can also lead students through activities like quiz games on the sphere or utilize professional academic functions such as displaying mind maps.

Ora Device Structural Design

The ORA features a precision metal base housing all system components, paired with a resin sphere possessing unique optical properties capable of displaying exceptionally bright and clear images. The device supports advanced gesture recognition for up to 10 users, enabling seamless interaction through infrared technology and artificial intelligence. Its 7.1 sound field system, equipped with 8 speakers and a subwoofer, provides immersive 360-degree surround sound, perfectly matching the stereoscopic projection effects to co-create an immersive experience.

Sphere

Crafted with multi-layer coating technology, it offers impact resistance and lasting durability. This material not only significantly enhances image brightness but also achieves exceptional pixel-

free color reproduction.

Metal Weighted Base

The sturdy metal base provides comprehensive protection for the projection system, with all four sides customized for personalized color schemes.

Wheels

Equipped with wheels featuring brake devices, the entire ORA system can be moved easily while ensuring stability and safety when stationary.

Lens System

The wide-angle lens group, composed of multiple aspheric optical lenses, ensures uniform 360-degree image surface coverage, eliminating light distortion. This optical system fully renders the precise images output by the 4K projector, achieving crystal-clear picture quality with excellent light transmission and contrast, guaranteeing true-to-life color reproduction.

Camera System

Infrared cameras detect all human movements on the sphere's surface, accurately interpreting interactive gestures like touch, double-tap, and drag through algorithms. Leveraging massively parallel GPU processors, the touch system offers exceptional sensitivity, consistently providing a smooth user experience.

Sensor System

Relying on a monitoring matrix composed of a ring of 98 infrared LEDs (940nm) and infrared cameras, the system can simultaneously recognize real-time operations from up to 40 touch points.

➡ Digital Presentation of the Timeline of Chinese Civilization

To deploy the ORA device for museum display, the ORA Sphere will be paired with a fully synchronized large flat screen. The sphere will act as a space-time navigator, while the tablet screen provides complementary information on the various themes displayed.

On the sphere, a vast timeline covering the entire history of Chinese civilization will be presented.

Ⅰ. Prehistoric and Bronze Age (c. 5000 BC – 221 BC)

Neolithic cultures (Yangshao Culture, Longshan Culture, etc.): Painted pottery, geometric patterns, early ritual symbols.

Bronze Age (Shang and Zhou dynasties): Ritual vessels (dings, guis), jade artifacts, early decorative items associated with ancestor worship and ceremonies.

Ⅱ. Unification and the First Empire (Qin and Han dynasties, 221 BC – AD 220)

Qin dynasty: Terracotta Army of the First Qin Emperor.

Han dynasty: Elaborately decorated tombs, painted lacquerware, silk, early landscape paintings. The emergence of Buddhist influence (late Han dynasty).

Ⅲ. The Flourishing of Classical Art and Buddhist Art (Three Kingdoms to Tang dynasty, 220 – 907)

Painting and calligraphy established as major art forms.

Buddhist cave temples (Dunhuang, Longmen, Yungang) with murals and large-scale sculptures.

Tang dynasty: Golden age of painting (landscape, portraiture, court scenes), export of ceramics (Tang Sancai).

Ⅳ. Maturity and Cultural Refinement (Song to Yuan dynasties, 960 – 1368)

Song dynasty: Landscape painting ("shanshui"), delicate brushwork, Neo-Confucian philosophy. Exquisite ceramics (celadon, porcelain).

Yuan dynasty (Mongol rule): Rise of literati painting (often monochromatic ink paintings), highly individualistic and poetic art.

Ⅴ. Late Imperial and Modern Transformation (Ming and Qing dynasties to the 20th century)

Ming dynasty (1368 – 1644): Proliferation of blue-and-white porcelain, grand architecture (Forbidden City), flourishing decorative arts.

Qing dynasty (1644 – 1911): Dominance of court art alongside the emergence of individualistic styles and regional painting schools.

20th century: Interaction between traditional and Western art, birth of modern Chinese art.

3

Archaeological Research

推动地中海文明
考古合作—中突合作

突尼斯本·阿鲁斯森林遗址
考古发掘项目

ADVANCING MEDITERRANEAN
ARCHAEOLOGICAL COOPERATION

THE CHINA-TUNISIA JOINT EXCAVATION PROJECT AT
THE BEN AROUS FOREST ARCHAEOLOGICAL SITE

多学科研究
MULTIDISCIPLINARY RESEARCH

数字复原呈现
DIGITAL RECONSTRUCTION

联合考古新范式
NEW PARADIGM FOR JOINT
ARCHAEOLOGY

01

Promoting Collaboration in Archaeology of Mediterranean Civilizations: China-Tunisia Joint Archaeological Excavation Project at the Ben Arous Forest Archaeological Site, Tunisia

▶ Applicant Institution

National Centre for Archaeology (NCA), National Cultural Heritage Administration (NCHA), China

▶ Participating Institution

National Heritage Institute – Tunisian;
Tsinghua Heritage Institution for Digitization, Ltd.（THID）；
ICOMOS International Conservation Center-Xi'an (IICC-X)

This project pioneers a new paradigm for cross-cultural archaeological collaboration, achieving deep integration of shared academic standards, multi-stakeholder coordination, and mutual learning. As the first archaeological cooperation between China and Tunisia, its breakthroughs include: Firstly, establishing joint work standards applicable to both parties, developing multilingual technical specifications and databases to form a replicable transnational archaeological collaboration system. Secondly, innovating a coordination mechanism between government agencies, NGOs and experts that integrates multinational academic expertise and promotes the application of multidisciplinary technologies (such as digital reconstruction, material analysis) in archaeology. Thirdly, transforming archaeological achievements into vehicles for civilizational dialogue through public open days and international training programs, not only filling gaps in relevant academic fields but also serving as a practical model for civilizational exchange under the Belt and Road Initiative framework.
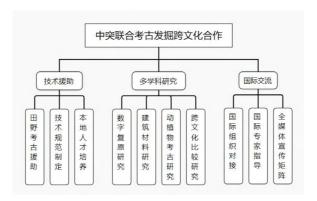
➔ **Opportunities and Collaborative Needs for Archaeological Cooperation**

Tunisia, located on the western shore of the Mediterranean Sea, is a confluence of diverse civilizations. It boasts rich heritage sites from the Punic and Ancient Roman periods, making it a hotspot for global ancient civilization studies and an important participant in the Belt and Road Initiative. In 2019, the Ben Arous Forest archaeological site was discovered during the construction of the Tunisia Ben Arous Youth Sports Center project, aided by China. Dating from the 3rd century BC to the 6th century AD, the site contains abundant remains. To advance cultural exchange and mutual learning, the relevant institutions signed a cooperation agreement in 2023, launching a joint archaeological project.

The project addressed several key collaborative aspects: firstly, establishing archaeological work standards applicable to both parties, covering excavation norms, intellectual property sharing, and multilingual collaboration models; secondly, integrating the professional strengths of multiple parties to build an efficient cooperation platform and fully leverage human and technological potential; thirdly, exploring diverse methods to present the cooperative results, ensuring the site's value benefits both local communities and the international audience.

➔ **Technical Framework and Implementation Pathway for Joint Archaeology**

The project constructed a tripartite technical system with archaeology as the core, conservation as the bottom line, and presentation as the medium, integrating technical assistance, multidisciplinary research, and talent development. Implementation proceeded in three phases. The preparatory phase involved clarifying the top-level design, signing the cooperation agreement, formulating multilingual technical standards and work templates, and developing the site information system and database. The field archaeology and research phase involved forming a joint archaeological team, completing a 130,000 square meter archaeological survey and 1,700 square meters of excavation, advancing multidisciplinary research including materials science and archaeobotany/zooarchaeology, conducting digital reconstruction, and providing

over 300 in-person sessions of training for Tunisian personnel. The results-sharing phase involved sharing outcomes with the public and international community through events like embassy cultural activities and international open days.

➲ Multidimensional Innovative Practices of the Joint Archaeology

The project achieved breakthroughs in multiple aspects.
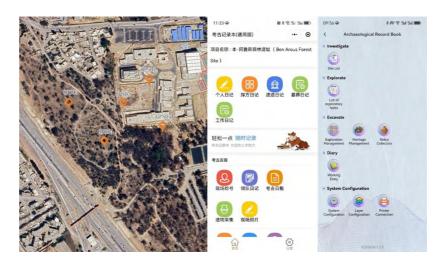
Establishing a new paradigm for China-Tunisia joint archaeology. Co-compiling the *Field Excavation Technical Standards for the Ben Arous Forest Site*, which specified norms for grid system setup, stratigraphic division, etc., developing a bilingual (Chinese-English) excavation database, and creating trilingual (Chinese-English-French) work templates, enhancing cooperation efficiency and standardization.

Building an "official-non-governmental-expert" organizational mechanism. Led by the institutions from both countries, it collaborated with international organizations and experts from multiple nations, strengthening cooperative ties.

Innovating multidisciplinary research methods. Conducting material studies on various unearthed

artifacts and construction materials, as well as non-destructive testing of precious cultural relics. Exploring new models for digital reconstruction. Employing 360-degree panoramic mapping and high-definition image synthesis technology, combined with historical literature and regional characteristics, to complete digital reconstructions, forming a traceable technical workflow.

➲ Diverse Outcomes of the Archaeological Cooperation

The project has achieved remarkable results. In terms of archaeology, the site layout has been clarified, and various remains from the Punic to Roman periods have been discovered. It has been initially divided into four functional areas, with the workshop area potentially being the largest ancient Roman dyeing workshop in North Africa, earning high recognition from Tunisia. In terms of media, the project has been covered by mainstream media in both countries, reaching an online audience of over ten million. On the public level, it has gained support from the local community and been praised by international experts as a model window for Mediterranean civilization studies. In the education field, a large number of talent training programs and public archaeology activities have been carried out, such as the International Open Day and China-Tunisia Archaeological Training Program, promoting knowledge sharing.

数字鲸落

DIGITAL WHALE FALL

"南海Ⅰ号" 考古发掘

ARCHAEOLOGICAL EXCAVATION OF "THE NANHAI NO. 1 SHIPWRECK"

水下文化遗产保护的全球范式
A Global Paradigm for Underwater Cultural Heritage Conservation

联合国教科文组织世界水下考古史的经典案例
A Classic Case Recorded in UNESCO's Global History of Underwater Archaeology

发掘单位：广东省文物考古研究院、国家文物局考古研究中心
Excavation Unit: Guangdong Provincial Institute of Relics & Archaeology, National Centre for Archaeology

02

Digital Whale Fall – The Archaeological Excavation of the Nanhai No. 1 Shipwreck

▶ **Submitting Institution:**

Guangdong Provincial Institute of Cultural Relics and Archaeology

▶ **Participating Institution**

Guangzhou Okay Information Technology Co., Ltd.

This project innovatively established a tripartite digital protection system for underwater heritage integrating archaeological excavation, on-site conservation, display and utilization. It pioneered an aerial intelligent surveying platform and non-contact acquisition technology, achieving millimeter-level precision positioning and the safe excavation of densely packed artifacts, solving problems of operating in confined spaces and conserving fragile cultural relics. It established a dynamic monitoring and incremental updating mechanism to track hull deformation in real-time with automatic alerts, simultaneously integrating multi-source data to form an archaeological semantic database, breaking down "data silos". It innovated a model of integral salvage, indoor excavation and VR reconstruction, which not only completely preserves information from the entire archaeological process but also brings the historical and cultural significance of the 180,000 recovered artifacts (sets) to the public through immersive experiences. This provides an exemplary paradigm of technical precision and cultural revitalization for global underwater cultural heritage protection

➲ Core Needs for Digital Protection of Underwater Heritage

The Nanhai No. 1, a Southern Song Dynasty shipwreck, is a rare underwater cultural heritage site (180,000 pieces and sets of artifacts were excavated), whose conservation and excavation face unique challenges.

Artifacts are densely packed and the environment is fragile. Objects within the ship's holds are stacked layer upon layer, leaving limited operating space. Centuries of seawater immersion have made the artifacts and wooden hull extremely susceptible to damage, rendering conventional excavation methods inadequate.

Tension exists between data acquisition and dynamic conservation. Frequent data collection risks causing secondary damage, and the lack of a real-time monitoring mechanism makes it difficult to capture minor hull deformations.

Transforming archaeological findings is challenging. Multi-source data (excavation records, artifact models, environmental data) lacked unified standards, hindering spatial-temporal correlation analysis of the hull, the artifacts and the environment and making specialized results difficult to communicate accessibly. Therefore, the project utilizes digital technology to balance excavation precision, conservation safety, and cultural dissemination, granting this underwater "cultural whale fall" a digital afterlife.

➲ Tripartite Digital Conservation Technical Framework

The project builds a technical system centered on precise excavation, dynamic conservation, and utilization", with all components working synergistically.

Archaeological Excavation Technology. An industrial-grade precision control network ("4 reference points + 0.5" total station) was set up. An aerial intelligent platform was developed, integrating a bi-directional gantry crane, laser scanning, and photogrammetry. This platform moves on rails enabling multi-angle non-contact acquisition, recording the 3D coordinates and stratigraphic relationships of artifacts. For densely packed artifacts within holds, an

innovative model of process involving group extraction and batch recording was created, using trigonometric leveling for millimeter-level positioning to avoid manual handling.

On-Site Conservation Mechanism. A hull deformation monitoring system was constructed to collect strain data from hull planks in real-time, issuing automatic alerts if thresholds are exceeded. A mechanism for incremental data updates was established, employing grid retrieval and classification recognition algorithms combined with automatic 3D texture mapping, enabling rapid local data updates and providing dynamic data support for restoration and research.

Display and Utilization Innovation. A multi-source integrated archaeological semantic database was built, storing data classified by spatial-temporal and attribute criteria, enabling cross-category intelligent retrieval through semantic associations. VR technology is used to recreate the archaeological site, creating a "single map" for holistic visual management, allowing the public to immersively observe artifact accumulation patterns and understand the history of maritime trade during the Song Dynasty.

➡ Innovative Breakthroughs and Practical Results

The project achieved multiple breakthroughs in technology, methodology, and value transformation, with significant results.

Technological and Methodological Innovation. The project pioneered an aerial intelligent surveying platform, filling the gap for non-contact high-precision acquisition in underwater archaeology. The model of integral salvage, indoor excavation and real-time digitization preserves information from the entire archaeological process intact. It obtained 7 national patents and fostered interdisciplinary talents such as digital archaeological technicians who have participated in over 20 domestic and international underwater archaeological projects.

Social Benefits. It recovered 180,000 pieces and sets of artifacts (including 198 Grade I cultural relics), promoting the standardization of underwater archaeology discipline and becoming a "Chinese solution" for international underwater heritage protection. Through international exhibitions (cooperating with the UK, the Netherlands, etc.) and educational base development, it disseminates Maritime Silk Road culture and enhances maritime cultural confidence.

Economic Benefits. Using the Nanhai No. 1 as a core attraction helped turn Hailing Island into a National 5A-level tourist attraction, forming an industrial chain comprising archaeological research, cultural tourism consumption, and creative cultural product development, promoting multi-industry integration and injecting new momentum into the regional economy.

➡ Ongoing Deepening of Technological Innovation and Scenario Expansion

The project will continue to deepen technological innovation and expand application scenarios, promoting the advancement of underwater heritage protection.

Technology Upgrade. Relying on an AI lab, develop new hull reinforcement materials and

intelligent artifact restoration techniques (point cloud understanding, fragment matching), construct an ink inscription recognition database and a spatial–temporal feature knowledge graph to mine correlation information of the Song Dynasty maritime network.

Experience Expansion. Create an "Underwater Archaeological Theme Park" (with naked–eye 3D and VR interaction), bring archaeology into schools (by donating replicas and AI teaching systems), and develop digital cultural creative products. Hold international academic seminars annually, conduct joint archaeological projects with countries along the Belt and Road, and cultivate cultural exchange envoys.

Safeguarding Mechanisms. Establish a conservation fund, form interdisciplinary teams with universities and enterprises, and set up technical backup and copyright review mechanisms to ensure sustainable project operation and compliance in international cooperation.

03

▶ **Applicant Organization:**

RUME Cultural Management Co., Ltd.

The Application of Technology and Artificial Intelligence in Enhancing Cultural Heritage Value and Safety Protection: An RUME Project Case Study
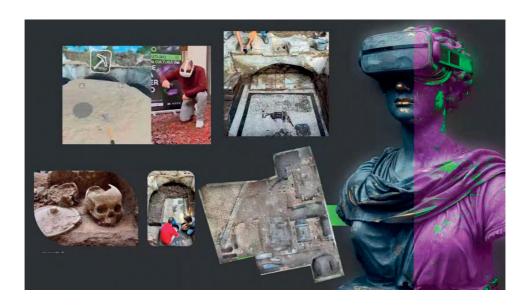
This case study deeply integrates cutting-edge technologies (such as Virtual Reality, AI, and Digital Humans) with cultural heritage management. It not only constructs immersive cultural experiences to enhance public engagement but also ensures heritage safety and sustainability through a comprehensive security framework and green technology. In doing so, it provides a replicable and scalable international digital solution for cultural heritage.

➔ The Need for Digital Transformation in Cultural Heritage

The field of cultural heritage management is undergoing a paradigm shift driven by digitalization. Finding a balance between preserving heritage authenticity and enhancing its accessibility is a crucial challenge. On one hand, global institutions like museums and archaeological sites need to blend traditional conservation methods with contemporary digital technologies to adapt to the interconnected digital age. On the other hand, they must respond to the diverse public demand for cultural heritage while ensuring its safety and sustainability. This process requires integrating cutting-edge technology with professional curatorial knowledge to build immersive cultural experiences, bridge heritage conservation and community participation, and form sustainable digital transformation models.

➔ Immersive Technology Empowers Enhanced Cultural Experiences

Leveraging innovative immersive technologies helps promote the diverse presentation of cultural heritage value. The Italian Meta Versus Culturae platform connects academic research with digital solutions. In the Belriguardo Museum project in the Emilia-Romagna region, video mapping and interactive technologies were used to transform ancient artifacts into vivid immersive narratives, making the traditional museum experience more engaging. The "Museo Diffuso del Brigantaggio" in Santa Maria, Abruzzo, employs a distributed network to connect physical sites with virtual experiences, achieving a cohesive narrative across geographical boundaries while maintaining local cultural authenticity, thereby enhancing regional cultural value.

➲ Innovative Integration of AI and Community Participation

Artificial intelligence can be used as a link to foster deep community involvement in building cultural narratives. In the "My Naples – An Exhibition of a Thousand Curators", the integration of AI technology with community participation enabled more diverse and democratic cultural interpretation, while remaining aligned with academic standards. This model respects professional expertise while incorporating public perspectives, thereby generating collectively constructed cultural narratives and strengthening the community's emotional connection to its cultural heritage.

➲ Interactive Fusion of Education and Technology

Integrating virtual reality and educational gamification into archaeological settings makes historical knowledge easier to understand and accept. The Campo Valano cultural heritage project incorporates virtual reality technology to design interactive learning experiences, transforming complex archaeological knowledge into intuitive immersive content. This approach breaks the one-way communication model of traditional education, allowing users to actively acquire knowledge through participation, thus enhancing the educational value of cultural heritage.

RUME / APPRENDO: THE CAMPO VALANO PROJECT

➲ Deep Integration of Digital Humans and Historical Settings

Introducing digital humans and AI-driven interfaces into historical environments enhances the authenticity and interactivity of cultural experiences. The Appian Way Interactive Station project uses digital human technology to build a bridge for dialogue with historical scenes. The

technological application does not obscure the authenticity of the culture itself but serves as an auxiliary tool, allowing users to perceive historical settings more intuitively and deepen their understanding of cultural heritage.

RUME / KEIRON : THE APPIA PROJECT

➲ Innovation in Accessibility for Underwater Heritage

The specificities of underwater heritage can be addressed by using advanced visualization technologies to broaden experiential access. The UTHRED project developed complementary experiences for both diving and non-diving visitors, using technology to overcome the physical limitations of underwater heritage. Whether through firsthand exploration by divers or virtual experiences for non-divers, the value of underwater heritage can be appreciated through technological means, significantly improving accessibility for this particular type of heritage.

➲ Building a Comprehensive Security and Sustainability Framework

Constructing an integrated framework encompassing security assurance and green sustainability is important to safeguard cultural heritage. The SSMIS project, coordinated by the Ministry of Culture and the Ministry of the Interior, invested 44 million Euros to establish an operational center providing comprehensive security management services for specific areas, relying on advanced technology to build a distributed security architecture. Simultaneously, the Intelligent Green Service Center (IGSC) employs eco-friendly technologies, supporting digital operations while achieving near-zero CO_2 emissions, thus addressing both security protection and environmental sustainability.

The 3D digital reconstruction of the Zun plate of Marquis Yi of Zeng | 三维数字化复原

曾侯乙尊盘

三维数字化复原

The 3D digital reconstruction of the Zun plate of Marquis Yi of Zeng

湖北省博物館
HUBEI PROVINCIAL MUSEUM

04

The 3D Digital Restoration of the Marquis Yi of Zeng's Zun and Basin

▶ **Applicant Organization:**

Hubei Provincial Museum
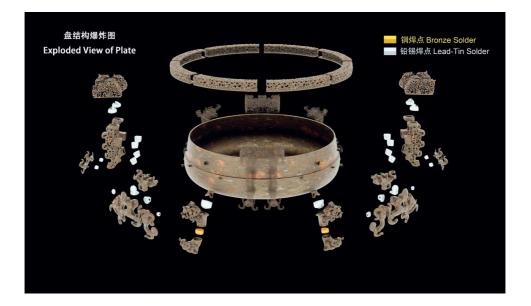
▶ **Participating Institution:**

The Palace Museum

The Marquis Yi of Zeng's Zun and Basin are two bronze vessels where numerous challenges lie in craft research, replication, display, and utilization due to their complex structure and casting techniques. Digital technology offers an effective approach to address these issues. However, traditional digital methods for information capture could only acquire surface structure data, failing to reveal the internal structure. This case study moves beyond traditional surface digitization techniques by utilizing the penetrative power of high-energy rays to acquire internal structural information. It conducts in-depth research from a bronze casting perspective to determine the forms, quantities, and connection methods of the main body and attachments. Video animations vividly present the intricate structure of the Zun and Basin

➲ The First Complete Presentation of the Full Structure of the Multi-Layered Openwork Attachments

This case employs industrial-grade computed tomography (Industrial CT) technology, constructing a full-chain technical framework of Data Acquisition → Intelligent Processing → Academic Analysis → Application Transformation. Through a 600kV micro-focus industrial CT system, high-penetration, non-destructive scanning was performed on the Zun and Basin, successfully obtaining millimeter-level 3D data (0.1mm precision) of their internal structures for the first time, overcoming the limitation of traditional X-rays in analyzing high-density materials. The implementation progressed through five stages.

Data Acquisition. Through dual-energy CT scanning parameter optimization technology, the Zun and Basin were scanned separately. Energy spectrum filtering reduced metal artifacts, acquiring the original 3D data model of the Zun and Basin.

Data Processing. The data model was digitally processed sequentially using data processing software. Optimization processing enhanced image quality, removed background noise, and reduced scan data artifacts. Data rendering involved fitting image paths based on the artifact's shape, texture, and structural information, achieving high-fidelity surface data fitting, rendering bronze textures, and generating a complete data model. Format conversion transformed the data into universal RAW and STL formats.

Technical Research. Based on the data model and leveraging density differences between lead-tin solder points and copper solder points, the structure, quantity, and connection methods of the main bodies and attachments were analyzed from a bronze casting perspective. Research revealed

that the Zun comprises a main body, 33 attachments, and 19 U-shaped locks, joined together by 32 lead-tin solder points and 23 copper welds. The Basin plate comprises 1 main body and 44 attachments, joined by 8 cast-on connections, 52 lead-tin solder points, and 4 copper welds.

Model Disassembly. Based on the technical research findings, the data model was segmented. This involved extracting the Zun's 32 lead-tin solder points, 23 copper weld points, 33 attachments, and 19 U-shaped locks; and extracting the Basin's 44 attachments, 8 cast-on points, 52 lead-tin solder points, and 4 copper weld points. A parametric topological relationship matrix for 98 components was established, enabling the dynamic separation and recombination of attachments.

Video Production. Following the Zun and Basin's manufacturing sequence, the segmented data model was used to create a video visualizing the digital disassembly and reconstruction of the artifacts. This allows the public to easily understand the complex structure and exquisite craftsmanship of this significant bronze artifact.

Compared to traditional methods, this case study, on a technical level, uses industrial CT 3D internal structure imaging instead of surface mapping, presenting for the first time in its entirety the complete structure of the multi-layered openwork attachments and accurately clarifying the quantities and connection methods of the main bodies, attachments, and solder points of the Zun and Basin. On a communication level, it uses interactive dynamic disassembly videos instead of graphic panels, significantly enhancing audience comprehension of the manufacturing techniques.
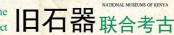
Case Practice Results

This case study clearly showcases the internal structure of the Zun and Basin for the first time, presenting their complex construction, excavating and interpreting the cultural relic's connotations, and demonstrating ancient craftsmanship and artisan spirit. It holds significant

importance for telling China's stories well, disseminating China's voice, and enhancing the dissemination impact of Chinese civilization. The results, presented in video format, bridge the gap between the public and cultural heritage/ancient technological civilization, endowing the artifacts with new vitality. Transforming static objects into dynamic digital content extends the informational richness of the relics, enhances readability, and achieves digital preservation and protection of the artifact's essential information, creating a sustainably usable cultural resource. This application of modern technology and large-scale equipment for digital restoration brings cultural relics to life, provides a model for CT data utilization, and promotes innovation in the scientific conservation of cultural relics.

The case established 3D models enabling 1:1 replication and unlimited printing for cultural creative design and R&D. Leveraging such advantage, probable collaboration with digital cultural creative companies can promote the importance of digital cultural relics, attract investment from enterprises and social capital, and jointly develop digital artworks and 3D models. This can not only create new revenue streams for museums but also presents the allure of cultural relics in new forms. Combining these results with modern media and leveraging platforms like Douyin and Weibo for cultural relic marketing campaigns can achieve heritage tourism promotion and big data applications. Furthermore, deeply exploring elements of the Zun and Basin for cultural relic IP development in animation, gaming, film, and television can enhance the integration and exchange of cultural relic resources within the entertainment industry. This allows cultural relics to enter the public view in more diverse ways, promoting the deep integration of cultural relic protection and utilization with the development of the cultural industry.

05

3D Modeling Technology Contributes to Sino-Kenya Joint Paleolithic Archaeology Project

▶ **Applicant Organization:**

Henan Provincial Institute of Cultural Heritage and Archaeology

▶ **Participating Institution:**

National Museums of Kenya

Kenya is a key region for studying human origins with rich Paleolithic remains distributed throughout the country, holding significant importance for exploring international academic topics such as the origins of modern humans. In 2017, the Sino-Kenya Joint Paleolithic Archaeology Project was launched, aiming to advance related research through cross-regional collaboration.
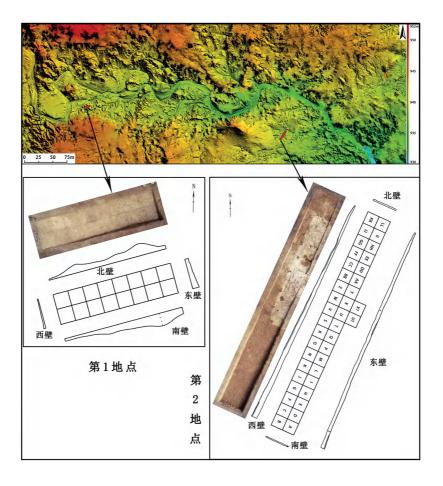
Archaeological research demands extremely high levels of objectivity, systematicity, and completeness in recording. However, traditional recording methods have limitations such as being prone to error and omission. With the proliferation of digital technology, methods like photographs, videos, and 3D models are gradually being applied to archaeological sites, but there is a lack of standardized operating procedures adapted to the entire process (survey, excavation, data processing). Therefore, the project explored integrating technologies like 3D modeling into the entire archaeological workflow to achieve precise recording of sites and artifacts, digital archiving, and cross-regional collaborative sharing.

➲ Building a Full-Process Digital Technology Framework

The project constructed a spatial information acquisition technology system based on the principles "multi-angle, multi-device, multi-method", integrating various digital tools to support the entire archaeological process.

Core Technologies. Including UAV aerial surveying (acquiring surface images, generating elevation maps and 3D models), 3D scanners (collecting high-density point cloud data of object surfaces, replicating physical forms), and high-precision GPS (achieving millimeter-level positioning, eliminating error effects), forming a stereoscopic data collection network from air to ground, from overall context to detailed features.

Implementation Pathway. Data collection was carried out phase by phase. Before excavation, UAVs captured aerial images of the area to produce schematic maps of the site location and elevation. During excavation, photo scanning was used to generate phased 3D models of the excavation site and unearthed lithics. During the data processing stage, 3D modeling was used to obtain high-precision models of stone tools, enabling micro-wear analysis and reduction sequence reconstruction.

➡ Innovative Breakthroughs and Experience in Digital Archaeology

The project achieved multiple innovations in technology application and process management.

Multi-dimensional Data Integration. Broke through the limitations of traditional single-perspective recording. By collecting data from multiple angles and with multiple devices, followed by integrated processing, it achieved a leap from 2D to 3D and multi-dimensional, more comprehensively reconstructing the characteristics of the site and artifacts.

Dynamic Recording and Sharing. Established a dynamic monitoring mechanism to update changes at the archaeological site in real-time, shifting from static snapshots to continuous recording. Simultaneously, a database was built to ensure secure data storage and international academic sharing.

Adherence to the principle of "Archaeology First". The application of technology always served the academic goals. Promoting the integration of digital technology throughout the entire archaeological process to avoid isolated steps. Appropriate technologies are selected based on research objectives and field conditions, and dynamically optimized operational procedures. The project has achieved significant results through the application of technologies such as 3D modeling.

Academic Discoveries. 63 Paleolithic sites were discovered in Kenya's Baringo region. The microliths found at the Kimengich site and the Levallois technique stone tools from the Lake Bogoria site provide critical evidence for studying the origins of microlithic cultures and their relationship to early modern humans. More than 8,000 stone artifacts and faunal fossils have been excavated in total, covering the Early, Middle, and Late Paleolithic periods.

Dissemination and Recognition. The project received extensive coverage by major Chinese media outlets, including Xinhua News Agency and CCTV, as well as several international news agencies. Live reporting of the excavation was broadcast on CCTV's *Morning News* program, reaching an audience of more than 4 million. The project was selected as one of the "Top Ten Cases of International Communication of Chinese Culture 2023-2024". The Lake Bogoria site became the only project selected for the Forum on Archaeology of the Chinese Academy of Social Sciences – New Foreign Discoveries 2023.

Cooperation and Public Outreach. The project promoted the sharing of technical equipment

between the Chinese and Kenyan teams, fostering localized archaeological capacity. It conducted public archaeology activities that invited local students for site visits and held popular science lectures, promoting awareness of cultural heritage protection.