

An Exploration of the Application of Digital Technology in the Preservation of Traditional Art Documents—A Focus on the Palace Museum Digital Relics Repository

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Abstract

Traditional art documents, as important carriers of Chinese civilization, face preservation challenges such as physical degradation and limited access. Digital technology offers a new path for systematic preservation. As an industry benchmark, the Palace Museum Digital Relics Repository's development and practice holds significant research value. This paper, using the Palace Museum Digital Relics Repository as a core case study, employs a combination of literature analysis and empirical research to systematically explore the application of digital technology in the preservation of art documents. The research finds that the platform, through a technological system encompassing high-precision data collection, knowledge graph organization, and intelligent management, has achieved the permanent preservation and open sharing of images of 100,000 cultural relics. Its comprehensive "collection-storage-utilization-dissemination" digitalization model not only addresses technical challenges in document preservation but also expands the boundaries of cultural communication. The research confirms that digital technology can effectively overcome the limitations of traditional preservation and provide technical support for the sustainable utilization of art documents. The Palace Museum's experience offers a replicable practical paradigm for the industry.

Keywords

Digital technology; Traditional art documents; Cultural relic preservation; Palace Museum Digital Relics Repository; Knowledge graph.

1. Introduction

Traditional art documents encompass diverse forms such as calligraphy and painting, inscriptions on stone tablets, and classics, carrying millennia of artistic wisdom and cultural heritage. As a cultural landmark housing 1.95 million artifacts, 90.3% of which are classified as precious, the Palace Museum's work in the preservation of art documents is highly representative. However, traditional preservation models face significant challenges: paper documents are susceptible to mold and brittleness due to temperature and humidity; the aging of mounting materials for paintings and calligraphy causes color fading; and the spatial and temporal limitations of physical exhibitions further confine most documents to seclusion. Statistics show that even a leading institution like the Palace Museum could only physically restore a few thousand documents annually in its early years, a process that carries the risk of secondary damage. Driven by the wave of digital globalization, information technology has revolutionized the preservation of art documents. Since launching its digitization project at the end of the last century, the Palace Museum has, over two decades later, built a digital cultural

relic database that has captured data on over one million artifacts, including 100,000 high-definition images available to the public, with over 33 million views. This practice not only changes the traditional logic of document preservation but also establishes a new ecosystem for cultural heritage characterized by "permanent preservation and sustainable utilization." Current academic research on the digitization of cultural relics often focuses on superficial technological applications, lacking in-depth analysis of single benchmark cases. Focusing on the Palace Museum's Digital Cultural Relics Repository, this article systematically analyzes the application mechanisms of digital technology in document acquisition, storage, restoration, and utilization, exploring its quality management and sustainable development experiences. This effort aims to provide theoretical and practical references for the digital preservation of traditional art documents and contribute to the dynamic inheritance of cultural heritage [1].

2. The Digital Shift in the Preservation of Traditional Art Documents

2.1. Limitations and Dilemmas of the Traditional Preservation Model

Traditional art document preservation has long relied on physical restoration and warehouse management, which presents inherent shortcomings. In the early years of the Palace Museum's restoration, a Song Dynasty stele or calligraphy scroll required over ten steps, including mounting, paper support, and full coloring, often taking 6-12 months. This restoration process relied heavily on the restorer's experience, making standardized protocols difficult to establish. Although physical storage utilizes constant temperature and humidity warehouses, natural material aging is inevitable. The fiber strength of some Ming Dynasty woven and embroidered documents decreases by an average of 2.3% annually. More critically, access to documents is limited. The Palace Museum exhibits fewer than 10,000 cultural relics annually, representing only 0.5% of its total collection [2]. Most art documents are difficult to access due to display case limitations and preservation requirements. Scholars must apply for access to the archives, but access is limited at any one time, and frequent physical contact accelerates document deterioration. This conflict between preservation and utilization has become a core bottleneck in the traditional model of art document transmission.

2.2. The Technological Inevitability of the Shift to Digitalization

Digital technology provides a path to address these issues, offering three major advantages over traditional models: non-contact collection avoids tampering with fragile documents; images exceeding 50 megapixels can capture microscopic details, such as pigment particles, far exceeding the capabilities of the naked eye; cloud storage overcomes physical space limitations; a single terabyte storage device can accommodate tens of thousands of document images, and data can be replicated and backed up indefinitely; and online communication breaks down barriers of time and space, enabling global sharing of documentary resources.

The Palace Museum's practice demonstrates the necessity of this shift. Since the launch of the Digital Cultural Relics Database in 2019, its standardized collection process has shortened the digitization cycle for individual documents to 48 hours, reducing collection costs by 95% compared to earlier times. The Palace Museum is currently collecting an average of 70,000 to 80,000 items annually, with plans to fully digitize 1.95 million cultural relics within 10 to 20 years, a scale unattainable with traditional conservation models.

2.3. Policy and Practical Background of Industry Transformation

The shift to digitalization is also supported by national policies. The "14th Five-Year Plan for Cultural Development" explicitly calls for "implementing a cultural digitization strategy," incorporating the digitization of cultural relics into key projects. The "Standards for the Museum Collection Information Index System," formulated by the State Administration of Cultural Heritage, provides a unified guideline for digitization practices. At the industry level,

projects such as the Dunhuang Academy's "Digital Dunhuang" and the Shanghai Museum's Dong Qichang Digital Humanities System have been launched, creating a wave of cultural relic digitization practices. The Palace Museum Digital Cultural Relics Repository was born against this backdrop. Its development has consistently adhered to the principles of "high-quality development" and "people-oriented." It not only digitally preserves documents but also upgrades "information preservation" to "knowledge services," building a comprehensive system integrating protection, research, and dissemination, setting a benchmark for industry transformation [3].

3. Technical Support System for the Palace Museum Digital Cultural Relics Repository

3.1. High-Precision Data Acquisition Technology Matrix

Data acquisition is a fundamental step in digital preservation. The Palace Museum has established a comprehensive acquisition technology matrix covering various types of art documents. For flat-panel documents such as calligraphy and painting, 6-billion-pixel ultra-high-definition imaging equipment is used to clearly capture the particle distribution of mineral pigments and the texture of silk in "A Thousand Miles of Rivers and Mountains." For three-dimensional objects such as ceramics and metal objects, non-contact 3D scanning technology is used to generate 720-degree rotatable digital models with an accuracy of 0.1 mm. The intelligent acquisition laboratory, jointly established with Tencent in 2023, has achieved even greater technological breakthroughs. The laboratory utilizes the "digital twin" concept, automatically adjusting environmental parameters such as lighting and humidity. Through virtual-reality fusion audio and video capture technology, it can output 12K ultra-high-definition images using only a green screen and a standard mobile phone. This technological innovation reduces acquisition costs by 95% and ensures the regular update of 15,000 to 20,000 items annually.

3.2. Intelligent Data Organization and Management System

Faced with massive digital resources, the Palace Museum has incorporated knowledge graph technology to build an intelligent management system. Based on the CIDOC-CRM international standard, a "Knowledge Graph of Ancient Chinese Movable Cultural Relics" was constructed, which structurally annotates over 20 attributes of documents, including dynasty, material, and decorative patterns. Semantic analysis technology enables intelligent searches such as "search by image" and "find by meaning." For example, a search term like "blue dragon-patterned porcelain" will link to related collections spanning the Song to Qing dynasties. Data storage utilizes a dual-backup model: local and cloud. Locally, it relies on the Palace Museum's data center's distributed storage system, while the cloud connects to the "Digital China" cultural relics big data system, ensuring data security and accessibility. A full-lifecycle quality management mechanism has also been established, referencing ISO 9000 standards and implementing over 20 quality control points across collection, processing, and storage to ensure data accuracy [4].

3.3. Immersive Display and Interactive Technology Application

To enhance the experience of using document resources, the Palace Museum has integrated a variety of interactive display technologies. The "Digital Treasure Pavilion" module uses 3D modeling to allow users to virtually explore cultural relics, allowing them to observe their details in 360°. The "Famous Paintings of the Palace Museum" module features a step-by-step zoom function for calligraphy and painting documents, allowing viewers to clearly see the structure of the buildings and the expressions of the characters in "Along the River During the Qingming Festival." The offline Dagaoxuan Hall Digital Museum utilizes a four-screen ultra-

high-definition display system, allowing for simultaneous comparison and appreciation of multiple documents. Regarding communication, a multilingual platform has been developed in five foreign languages, including English, French, and Japanese, incorporating AR guide technology to provide personalized tour route recommendations [5]. The virtual curation function, launched in 2025, allows users to independently combine document resources to create themed exhibitions. It has already incubated over 300 private exhibitions, forming a communication ecosystem characterized by "professional output + public participation."

4. Practical Applications of Digitalization in the Preservation of Art Documents

4.1. Digital Rescue Project for Endangered Documents

For endangered art documents, the Palace Museum implements a digital rescue strategy of "prioritizing acquisition and prioritizing preservation." For over 100 rare Song Dynasty inscriptions and calligraphy, data was collected without touching the originals using a combination of non-destructive spectral analysis and ultra-high-definition photography. The digital image of the Chunhua Ge Tie (Chunhua Ge Tie) fully preserves the original ink shades and traces of paper fiber damage. For severely aged embroidered and weaved documents, micro-trace analysis was used to assess their preservation before developing a customized acquisition plan. During the digitization of a Ming Dynasty Yongle blue-and-white plum vase with a lotus pattern, the technical team employed a combination of CT scanning and surface scanning to restore the vessel's overall shape and capture the subtle features of glaze cracking. These digitized archives serve as "digital backups" for endangered documents. Even if the originals are damaged, digital information can still be used for academic research and cultural dissemination [6].

4.2. Standardized Organization and Archiving of Documentary Resources

Standardization is a core requirement for digital preservation, and the Palace Museum has established a comprehensive standard system covering the entire process. During the data collection phase, the "Standards for Registration of Cultural Relics in Museum Collections" (WW/T 0017-2013) were strictly adhered to, with differentiated parameters set for different document types: calligraphy and painting documents were imaged at 50 megapixels or higher; ancient books required recording of the page size and line format; and inscriptions and rubbings focused on capturing the ink gradation of the rubbings. During the data processing phase, the "Digital Cultural Relic Image Quality Standards" were established, defining eight core indicators, including color reproduction and clarity, and using algorithms to automatically correct for image distortion. During the archiving phase, a unified metadata format was adopted, linking 15 basic information items and 6 linked data items to each document, enabling seamless integration with the "Digital China" cultural relics big data system. Currently, over 120 museums have adopted this standard system, promoting data interoperability and sharing within the industry.

4.3. Digital Empowerment for Restoration Assistance and Academic Research

Digital technology provides scientific support for document restoration. During the restoration of a Qianlong-era famille rose hollow revolving vase, the technical team used a 3D model to simulate the object's structure and anticipate restoration difficulties, reducing the actual restoration time by 40%. AI technology was also used to identify stains and conduct virtual restorations on ancient documents. By learning from restoration examples of similar documents, it automatically generated restoration plans for expert reference. This technology has significantly empowered academic research. The "Cultural Relic Comparison and Appreciation" feature of the digital cultural relic library allows scholars to simultaneously

access multiple documents from different dynasties for detailed comparisons. Since its launch in 2024, it has already supported over 30 art history research projects. Open high-definition image resources have lowered the barrier to entry for research, allowing scholars to access microscopic details of "A Thousand Miles of Rivers and Mountains" without having to visit the Palace Museum in person. The number of research papers published on this topic has increased by 27% [7].

5. The Preservation Effectiveness and Social Value of the Palace Museum Digital Cultural Relic Library

5.1. Long-term and Scaled Document Preservation

The digital cultural relic library has established a long-term preservation mechanism for art documents. As of June 2025, over one million cultural relics have been digitized, including 100,000 high-definition images included in the open database, covering 12 major categories, including ceramics, textiles and embroidery, calligraphy and painting. These digital resources, through multiple backups and technical encryption, are permanently preserved, completely addressing the vulnerability of physical documents. Large-scale conservation efforts have yielded remarkable result [8]. Traditionally, the Palace Museum could only systematically conserve a few hundred documents annually; however, digitization has increased this to 80,000. For treasures like "A Thousand Miles of Rivers and Mountains," digitization has enabled "one-time acquisition, sustainable use." Its digital images have been accessed 1.2 million times, effectively reducing the burden on the originals' display and extending their physical lifespan.

5.2. Globalization and Popularization of Cultural Communication

The digital cultural relic database has broken the temporal and spatial constraints of cultural communication, with cumulative views exceeding 33 million and users in over 70 countries worldwide. The launch of the multilingual platform has increased the proportion of overseas users to 23%, making it a key vehicle for cultural exchange along the Belt and Road Initiative. The "Digital Cultural Relics Detail Appreciation" series on short video platforms has reached a peak of 50 million views per piece, attracting a large number of young audiences. The national sharing mechanism is continuously improving. The "Digital Cultural Relics Classroom" resource package, developed for young people, has been adopted by over 2,000 primary and secondary schools nationwide [9]. A digital cultural and creative competition for the public has spawned popular products such as the "Tiangong Caisong" refrigerator magnet, with monthly sales exceeding 500,000 units. This "professional preservation + mass communication" model has brought art archives from the academic realm into everyday life.

5.3. Innovation and Sustainable Development of the Cultural Ecosystem

Digital preservation has fostered a cultural innovation ecosystem. The innovation lab jointly established by the Palace Museum and Tencent has developed over 10 innovative applications based on digital resources, including virtual curation and AR guided tours. The application of blockchain technology has enabled the standardized circulation of digital collections, providing a new path for the transformation of cultural resources. The API openness plan, launched in 2025, will further encourage global scholars to participate in the in-depth mining of archival data. A sustainable development model is gradually taking shape. Through a diversified investment mechanism combining "government leadership, enterprise collaboration, and public participation," funding challenges for digitization have been addressed. The implementation of a quality management framework ensures stable resource output, laying the foundation for the full collection plan over the next 10-20 years. This sustainable model not only ensures the long-term preservation of the Palace Museum's archives but also provides a valuable operational model for the industry [10].

6. Existing Problems and Optimization Paths in the Digital Preservation of Traditional Art Documents

6.1. Core Challenges of Current Practices

Despite significant achievements, the Palace Museum's digital cultural relic database still faces multiple challenges. Technically, there's the risk of "data silos." Some early-collected document data, due to outdated formats and lack of compatibility with existing systems, requires additional costly format conversion [11]. The standard system is not yet fully unified, and some data standards differ from those of institutions like the Dunhuang Academy, hindering cross-institutional resource integration. Funding and talent bottlenecks are prominent. The high-precision digitization cost of a single artifact still reaches hundreds of yuan, and full collection requires substantial ongoing investment. A 70% shortage of interdisciplinary talent with both professional knowledge of art documents and digital technology hinders the in-depth application of technology. Data security risks are also not negligible, and copyright protection and anti-leakage measures for massive amounts of high-definition images need to be further strengthened.

6.2. Technical Optimization Directions

Technological upgrades should focus on three key areas: First, building an adaptive data compatibility system, using artificial intelligence to automatically identify and convert legacy data formats, enabling seamless integration of new and existing resources; second, promoting the internationalization of standards, integrating existing standards with international standards such as CDWA and DCMES, and participating in the development of a global cultural heritage digitization standard system; third, strengthening security protection by adopting blockchain technology to achieve data traceability and combining encryption algorithms to prevent unauthorized access. The level of intelligence needs to be further enhanced. Develop an AI-assisted document interpretation system to automatically identify text and pictorial information in ancient books; construct a large-scale virtual restoration model, learning from millions of restoration cases to provide more precise restoration solutions for endangered documents [12]. In-depth application of digital twin technology can enable real-time monitoring and intelligent control of the document preservation environment to prevent physical damage.

6.3. Ecosystem Improvement Strategies

Improving multi-faceted collaborative mechanisms is key. Deepen the "library-enterprise cooperation" model, expand cooperation with technology companies, and address funding and technology iteration issues; establish a "cross-library alliance" to jointly build and share databases with institutions such as the Dunhuang Academy and the Shanghai Museum, and promote the integration of industry resources. Public participation mechanisms need to be further expanded. Through the "Digital Cultural Relics Volunteer" program, the public should be encouraged to participate in the annotation and proofreading of document information. Policies and support systems should be simultaneously improved. The digitization of cultural relics should be included in the key support areas of the National Cultural Development Special Fund, and a long-term investment mechanism should be established. Universities should establish interdisciplinary disciplines in "Cultural Relics Digitalization" to cultivate interdisciplinary talent. Laws and regulations should be improved to clarify the copyright ownership and usage rules of digital cultural relics, balance open sharing with intellectual property protection, and build a healthy and sustainable digital preservation ecosystem [13].

7. Conclusion

The development of the Palace Museum's Digital Cultural Relics Repository fully demonstrates the core value of digital technology in the preservation of traditional art documents. Through the application of high-precision data collection, intelligent management, and immersive communication technologies, the platform not only enables the permanent preservation and open sharing of 100,000 art documents, but also establishes a comprehensive digital ecosystem encompassing "preservation-research-dissemination-innovation," setting a benchmark for the industry. Its experience in technological innovation, standard development, and ecosystem building has resolved the core contradiction between "protection and utilization" in traditional preservation models, demonstrating the unique advantages of digital technology in transcending spatial and temporal constraints, improving preservation efficiency, and expanding cultural value. Currently, the digital preservation of traditional art documents still faces common challenges such as technical compatibility, standardization, and talent shortages [14]. Future development should build on the Palace Museum's experience and promote optimization along three dimensions: At the technical level, achieve an upgrade from "digitalization" to "intelligence," enhancing conservation precision through AI and digital twin technologies; at the industry level, build a collaborative network with unified standards and shared resources to break down institutional barriers; and at the ecological level, foster a diversified ecosystem characterized by "government guidance, museum-enterprise collaboration, and public participation" to ensure sustainable development. Digital technology offers not only innovative technical means for the preservation of traditional art documents but also an upgrade in conservation philosophy—moving from simple physical preservation to living transmission. The Palace Museum's digital cultural relic repository demonstrates that only by deeply integrating technological innovation with cultural connotations can millennia-old art documents be revitalized in the digital age, providing solid support for the sustainable inheritance of Chinese civilization.

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