

Research on Digital Intelligent Protection and New Format of Cultural Heritage Based on XR Digital Technology

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Abstract. In order to cope with the strategic needs of systematic protection of national cultural heritage, this study focuses on the "data silo dilemma" faced by ancient building restoration and the double pain points of "technology stacking trap" and "hollowing out of cultural connotations" of traditional laser show. This study focuses on the "data silo dilemma" and the "technology stacking trap" and "hollowing out of cultural connotations" faced by the traditional laser show restoration of ancient buildings, and proposes a path to digitalization. Zhengding Longxing Temple as a model case, the first dual-platform synergistic system, ancient building restoration digital intelligence generation platform, through intelligent data collection, AI diagnosis, restoration program generation, process simulation and digital archive system, to build a systematic restoration of the closed loop; XR digital laser show new form generation platform, based on the scanning of data, analysis of cultural elements and intelligent generation of the technology chain, to achieve the cultural connotation of the immersive effect driven by the innovation. Innovation. The two platforms take "technology-driven cultural living inheritance" as the core logic, and the results of the restoration platform directly empower the creation of laser show content, forming the whole chain of "protection-restoration-activation and display" upgrading. The research results not only overcome the problem of cultural heritage data integration and technology application, but also the national cultural digitization strategy to provide a replicable technology integration model, to promote the depth of synergy between science and technology and culture.

Keywords: Cultural Heritage Restoration, Intelligent Inheritance, Technological Expression Innovation, Digital Intelligence Generation.

1. Introduction

Domestic and foreign laser show performances are identical and lack differentiation. The restoration of ancient buildings faces the systematic dilemma of "data silos" - the lack of a unified database and intelligent restoration tools. The national policy of "systematic protection of cultural heritage" promotes the transformation of restoration into digital intelligence, and there is an urgent need to build a solution for the whole chain of "protection and revitalization". This project focuses on the integration of cultural heritage revitalization and science and technology to build an integrated solution of "protection and revitalization". On the one hand, it builds a digital intelligent generation platform for ancient building restoration and establishes a closed-loop system of "intelligent data collection system-AI diagnosis module-intelligent restoration program generation system-restoration process simulation and guidance-digital archive system". Through the "intelligent data collection system - AI diagnostic module - intelligent restoration program generation system - restoration process simulation and guidance - digital archive system" closed-loop system, the establishment of the ancient building model database and restoration system, to promote the restoration of ancient buildings from the "experience-driven" to the "data-intelligent" transformation, and systematic cracking of the traditional restoration problems. On the other hand, the AR laser shows as a revitalization carrier, relying on 3D scanning, laser projection and other technologies, the restoration of the platform's digital model into the ancient building texture + future light and shadow "immersive experience, covering a multi-scene cultural display. The two synergistic efforts to realize the whole chain of upgrading from accurate protection to innovative dissemination, injecting new momentum for the inheritance and utilization of cultural heritage.

2. Project Overview

Closely following the national strategic direction of "strengthening systematic protection of cultural heritage", ancient building restoration is facing the "data silo predicament", the lack of systematic information platforms and databases and other issues; accurate anchoring of traditional laser show and ancient building restoration in the field of core pain points. Traditional laser show caught in the "technology stacking trap", cultural connotation hollowed out leading to the audience experience superficial, the two major problems urgently need digital breakthrough.

National key cultural relics protection unit Zhengding Longxing Temple, for example, the first "ancient building restoration digital intelligence generation platform" and "AR digital laser show new form generation platform". It creates a national demonstration model for the protection and adaptive use of cultural heritage.

3. Market feasibility study of dual platforms for cultural heritage AR revitalization and digital intelligent protection

3.1. AR laser show generation platform feasible market analysis

3.1.1. The scientific and technological visual experience of AR laser show

The audience of AR laser show is broad and the application scene is diversified. The audience group of AR laser show widely covers audiences of different ages, genders, occupations and regions. Young audiences are keen to pursue freshness and excitement, and the unique visual effect of laser show is in line with their aesthetic needs. The family audience in the parent-child activities, through the laser show to enhance affection, cultivate children's interest in science and technology. Enterprises and institutions, festivals and tourist attractions, laser show has become an important means of attracting tourists and enhancing the brand image, laser show has a broad audience base, huge market potential, wide range of application scenarios.

3.1.2. Narrative reconstruction from physical dimension to symbiosis between reality and reality

Joint deep learning as well as three-dimensional reconstruction technology and other technical means to build a multimodal data system, can be three-dimensional modeling, deep learning and other technical means of convergent processing, to achieve digital reconstruction processing [1]. Reconstruction of its cultural association with contemporary society through digital media. On the one hand, the narrative mobility of cultural heritage is activated through digital media. The narrative of cultural heritage in the traditional protection mode is unidirectional and closed, relying on the static presentation of physical exhibition and the authoritative discourse of expert interpretation. Digital technology transforms cultural heritage into an open "field of meaning" by building an interactive narrative interface [2].

3.1.3. Color simulation based on three-color spatial mixing and brightness control

Using the principle of full color synthesis, the laser color output from the laser is monochromatic, but color laser demonstration can be realized based on the principle of three-base color mixing method in chromaticity. The realization of the full color of this system uses the spatial color mixing method to control the three lasers to emit different ratios of the three colors of the laser beam, the three-color laser beam after filtering and reflection projected onto the display screen adjacent to the three points. Because the human eye on the color discrimination ability is limited, as long as the three points are close enough, they can not distinguish the three basic colors, so the feeling is a mixture of their colors. At the same time, the laser brightness output by the laser can be adjusted, so theoretically, the laser is able to achieve an effective simulation of all colors[3].

3.2. Feasibility Market Analysis of Digital Intelligent Generation Platform for Ancient Architecture

3.2.1. Policy-driven Restoration Technology for Wooden Structures of Ancient Buildings

The state issued the "14th Five-Year Plan" for cultural relics protection and scientific and technological innovation and other policies to clearly promote the digital protection and utilization of cultural relics, and all over the world have also formulated relevant standards and initiatives. The concept focuses on the "make up for the new", the process focuses on empirical judgment, and the technical content is dominated by traditional materials and techniques. This technical system effectively maintains the development of traditional Chinese architecture, and becomes part of the "authenticity" of architectural heritage, but this traditional wooden structure repair technology can not fully meet the needs of modern architectural heritage protection, and at the same time, modern restoration and reinforcement technology can not make up for the shortcomings of the traditional technical system [4].

3.2.2. Technology-enabled restoration of ancient buildings

The demand for accurate restoration is increasing. Traditional restoration relies on the experience of craftsmen, which has the problems of low precision and poor efficiency. The demand for visualization and guidance is increasing, and the simulation of the restoration process and AR real-time guidance function can visually display the restoration effect, assist the operation of on-site construction personnel, and solve the problems of high communication costs and large operation errors in the construction process, which meets the market's expectations for a convenient and efficient restoration process. The platform carries out real-time monitoring through sensor technology on the horizontal displacement and settlement of the top of the ancient building, the deep horizontal displacement of the wall, the support axial force, the settlement of the columns, the settlement of the surrounding buildings, the cracks, the tilt monitoring, and the settlement and displacement of the surrounding underground pipelines, etc. The platform wirelessly transmits the data to the system, supports the APP of the cell phone and the PC to view the monitoring data of the ancient temple and the exceeding of the warning records, and grasps the construction impacts of the newly built Art Center in a timely manner. Impact on the construction of the new art center in a timely manner, to play a good role in the protection of the ancient temple building [5] .

4. Ased on data-driven and digital intelligence generation of digital twin heritage activation laser animation efficient generation and multi - dimensional interaction strategy research.

4.1. Digital twin technology for cultural relics revitalization to provide the whole chain support

4.1.1. From protection to revitalization of the virtual integration and industrial value reconstruction

The whole chain upgrade is from protection to activation of industrial value reconstruction of protection - display integration process digital acquisition 3D modeling to obtain the basic data of cultural relics→restoration simulation: test the restoration program on the digital model→laser show development: using the AR digital laser show new form generation platform, the production of animation projection with regional cultural characteristics→activation display: outdoor large-scale laser show or VR virtual exhibitions. Using XR technology virtual and reality collision, the project through AR and VR technology to carry out traditional culture and modern technology combination of virtual and reality collision. Cultural heritage restoration and laser show fusion presents three-dimensional value.

4.1.2. High-precision digital empowerment of cultural relics details immortalization and revitalization upgrade

Data on the restoration model can be directly imported into the laser show platform, creativity on the restoration program inspired by the theme of the show, technology on the three-dimensional modeling and other technology interoperability, to promote the upgrading from protection to revitalization of the show. High-precision digital acquisition adopts structured light scanner and LiDAR technology to carry out sub-millimeter three-dimensional modeling of the Longxing Temple architectural complex and ridge beasts, and combines AI-driven surface reconstruction and texture mapping technology to realize the digital immortality of cultural relics details.

4.1.3 All-round data acquisition and restoration support for ancient buildings

Using high-precision 3D laser scanners, structured light scanners or drone tilt camera equipment, all-round data acquisition is carried out to generate point cloud models with millimeter-level accuracy. The introduction of mechanization and automation provides solutions to these challenges. Taking the drone and laser scanning technology as an example, through high-precision 3D scanning, every detail information of the ancient building structure can be accurately obtained, which can provide more accurate data support for the subsequent restoration work and avoid the errors of traditional manual measurement. UAVs are also able to quickly and efficiently accomplish the tasks of shooting and detecting in high altitude and narrow spaces that are beyond the reach of traditional means [6] .

4.1.4. High-precision digital construction of cultural relics digital immortality cornerstone

AR digital laser show new form generation platform through high-precision 3D scanner equipment scanning scenic spots or museum models for the construction of the database, to achieve from the physical scene digitization to the intelligent generation of cultural content of the whole process of coverage, and ultimately the laser projection as a carrier, to create both a sense of technology and the depth of cultural immersive experience, so as to better use in a number of tourism scenarios and laser show of different cultures. Display. Through the closed loop of "data scanning→professional model processing→cultural element analysis→professional animation content outline processing→intelligent generation", the regional culture is transformed into an interactive dynamic narrative, avoiding the high labor cost and creative limitations of traditional animation production. Intelligent data processing through deep learning algorithms to automatically repair the defective parts of the model, the establishment of classification and labeling database, the establishment of traceable digital archives for cultural heritage.

4.2. Cultural technology integration practice of restoration and laser show

4.2.1. The whole process of intelligent generation of laser projection immersive experience

In this paper, the model of scenic spots or museums is scanned by high-precision 3D scanner equipment, and the model is imported into 3Dmax modeling software to be processed by technicians, and the technicians carry out the construction of the cultural database, and combined with the local cultural characteristics, the platform automatically generates an animation synopsis demonstration combined with the local characteristics and architecture, and combines the animation demonstration with the laser light equipment, and the platform realizes the whole process coverage from the digitization of the physical scene to the cultural content intelligent generation. The platform covers the entire process from physical scene digitization to intelligent cultural content generation.

4.2.2. Digital archive management and data support for the whole life cycle of ancient buildings

The digital archive management system establishes digital archives of the whole life cycle of ancient buildings, integrates information such as data collection, analysis and diagnosis, restoration plan and restoration process records, and realizes digital storage, retrieval and sharing of archives. It

provides complete data support for long-term monitoring, maintenance and research of ancient buildings.

4.3. Full-process digital restoration of ancient building restoration digital intelligence platform

4.3.1. Digital Intelligence Platform for Restoration of Ancient Buildings

The ancient building restoration digital intelligence generation platform relies on the "intelligent data acquisition system - AI diagnostic module - intelligent restoration program generation system - restoration process simulation and guidance - digital archive system" to build the ancient building model database and restoration system. The digital intelligence platform is expected to promote the transformation of ancient building restoration from "experience-driven" to "data-intelligent", establish synergy among the six functional modules, and build up a "data collection - analysis and diagnosis -Program generation - construction guidance - file management" closed loop system. Realize the balance of protection, inheritance and utilization.

4.3.2. Intelligent data collection, diagnosis, program generation and simulation guidance system

Intelligent data collection system is to collect all-round and high-precision data of ancient buildings through integrated equipment, and the AI analysis and diagnosis module utilizes artificial intelligence algorithm to deeply analyze the collected data of ancient buildings. It automatically identifies building structural damage, material aging and other issues, and combines with the knowledge base to generate a scientific building health assessment report. Intelligent Restoration Solution Generation System Based on the results of AI analysis, combined with the experience of building restoration experts and industry standards, the system automatically generates a variety of feasible restoration solutions by using technologies such as Generative Adversarial Network (GAN). Repair Process Simulation and Guidance Through virtual reality (VR) technology, a three-dimensional simulation demonstration of the selected restoration scheme is carried out to visually display the restoration process and expected results.

4.3.3. Panoramic Image Processing Helps Reproduce Details of Ancient Buildings

Image processing is mainly to ensure the quality and accuracy of the panoramic image in order to better display the details and characteristics of the ancient architecture. The first task is clarity and color correction to ensure that the image shows real, sharp visual effects. Next, image stitching is performed, a process that requires precise alignment of each photograph to eliminate inconsistencies in overlapping areas. Immediately after image stitching, dynamic range adjustments are performed to show the details of the ancient buildings under different lighting conditions. Finally, image optimization, including noise removal and sharpness adjustment, is performed to enhance the overall visual effect of the final panoramic image. Together, these steps ensure that the panoramic display can truly and vividly reproduce the charm of the ancient buildings [7].

4.4. Innovative expression of cultural content of time and space folding

4.4.1. Big Data Analytics and AR Immersive Narrative Enabling the Protection of Non-heritage and Revitalization of Cultural Relics

As an "intelligent brain" for accurate decision-making, big data analysis can provide in-depth insights for the protection and management of non-heritage. Through the real-time capture and in-depth analysis of massive data such as the number of visitors, feedback information, popularity index, etc. of the non-heritage big data platform, managers can accurately capture the public's interest in non-heritage projects and potential demand[8]. The AR immersive narrative system develops laser show animation-themed interactive experience spaces, AR encyclopedias of architectural components, and transforms static cultural relics into conversational cultural carriers.

4.4.2. Longxing Temple XR virtual experience to help cultural heritage

Cultural symbols meta-universalization reconstructs the religious ceremony scene of Longxing Temple through VR, and users can participate in virtual sacrificial activities through VIVE helmets to realize the digital inheritance of cultural practices. For example, the virtual tour system is designed so that visitors can "touch" the virtual spine beasts and hear the historical stories they tell through cell phones or AR glasses. This immersive experience not only increases the sense of participation, but also better conveys cultural information.

4.4.3. Data-driven laser animation efficient generation mode

Combination of laser show and animation: The use of digital laser monochrome directional luminescence enables the combination of laser show and animation, outlining every detail of the building. Collision of virtual and reality by using XR technology: technicians use AR and VR technology to combine traditional culture and modern technology for the collision of virtual and reality.

4.5. Visitor Experience Innovation and Cultural Creation Interaction --- Multi-dimensional Perception of Revitalized Cultural Relics

4.5.1. Visitor Experience Innovation - Multi-dimensional Perception Interaction

Mixed reality tour system is the tourists through the AR glasses to realize the "live guide + virtual reconstruction" seamless switching, the cell phone can be summoned to the virtual historical figures to explain the scene. Gamification exploration design sets up role-playing games such as "Ancient Building Restorer" and "Guardian of the Ridge Beast" in the VR experience area to deepen cultural knowledge through task-driven.

4.5.2. Cultural creation extension and interactive design to revitalize the value of cultural relics

The laser show derivative products and cultural creation design strengthen the interactive and educational attributes, design the multi-dimensional interaction between the users and the beasts, and launch the fingertip models, arch blocks and other cultural creations, integrating the traditional elements and modern design to meet the needs of the collection and popularization of science, attracting young people, and letting the culture integrate into the modern life in a diversified form. The laser show derivatives design the interaction between users and the beasts by touching the beasts with the VR handle. High-quality rendering engine is utilized to render the scene to ensure the clarity and realism of the picture. At the same time, the light and shadow effects are adjusted according to the time change to make the scene more vivid. Diversified touch feedback, the beasts will react differently according to the parts they touch. Sound and movement linkage, when users interact with the beast, the beast not only responds through movement, but also makes specific sounds to increase immersion. Intelligent behavioral response, the beast can have a certain AI logic. Tasks and Interaction Design some tasks related to the God Beast, and enhance the emotional connection between the user and the God Beast by completing the tasks. Scene detail optimization In the environment model of Longxing Temple, add more details to make the scene more realistic.

5. Technology empowers the sustainable future of cultural heritage

5.1. From the accumulation of light and shadow to the symbiosis of culture

Cultural connotation upgrading breaks through the traditional laser show "light and shadow stacking" mode, in-depth integration of Yanzhao culture (such as the Longxing Temple architecture, ridge beast symbols) and cyberpunk aesthetics, to give the technology performance with a sense of historical gravity. Through the excavation of historical stories behind the cultural relics, cultural symbols and regional veins, to realize the expression of "technology + culture + emotion" trinity.

5.2. Technological expression of innovation to help upgrade the presentation of ancient architecture and industry breakthroughs

Technical expression innovation adopts new scanning technology and digital means to accurately restore the details of ancient buildings, breaking through the limitations of traditional equipment on artistic expression. Modern visual language is used to reconstruct traditional cultural symbols, forming an aesthetic collision between the past and the present. Audience experience deepens from "short-lived visual stimulation" to "lasting cultural resonance", guiding the audience to understand the cultural connotations through narrative light and shadow design, and strengthening the memory points and emotional connection. Cracking the bottleneck of industry development and optimizing the allocation of resources: the current ancient architecture restoration market is facing problems such as lack of funds, faulty talents and chaotic data management. The platform integrates multi-source data through the establishment of a digital archive management system, realizing the efficient use and sharing of resources.

5.3. Digital Intelligence Technology and Traditional Culture Synergize to Empower the Protection and Inheritance of Ancient Buildings

At the level of value appeal, it constantly exerts the synergistic effect of digital intelligence industry and traditional culture industry, and in the process of deep integration of culture and technology, it breaks the time and space communication limit of culture and shows its eternal charm across time and space. Eternal Charm Across Time and Space[9]. In addition to relying on traditional craftsmanship and experience, the protection and restoration of ancient Chinese buildings is becoming more and more important by using modern scientific and technological means [10].

5.4. Deepening Cultural Heritage Protection and Inheritance

As a cultural carrier, ancient architecture carries historical memory and national spirit. The platform records the complete information of ancient buildings through digital twin technology, establishes full life cycle digital archives, and avoids the loss of cultural heritage due to natural damage or human factors. Helping policy landing and responding to national strategic needs: the construction and promotion of the platform is a positive response to policy orientation, providing technical support and practical path for policy implementation.

5.5. Project cultural activation and industry transformation and social communication value

The cultural level of the project activates the IP of cultural relics, spreads the cultural value of Zhengding Longxing Temple in an innovative form, and helps regional cultural inheritance. The technical level provides the traditional laser show industry with the paradigm of "content-driven technology", and promotes the transformation of the industry from showmanship to narrative. At the social level, the cross-border art form attracts young people to pay attention to traditional culture and enhances the educational and communication power of public art.

6. Conclusion

The project uses digital technology as a pen to write the future on the thousand-year-old spine of Longxing Temple. Through the in-depth collision of cyberpunk aesthetics and Yanzhao culture, the project breaks through the visual stacking mode of traditional light and shadow show, and reconstructs the expression paradigm of cultural heritage with the trinity of "technology+culture+emotion". Using high-precision scanning and digital twin technology to establish a full life cycle archive of ancient buildings, cracking the protection dilemma; innovative laser show as a carrier, the cultural relics IP into the cultural resonance of young people, to realize the experience from "short showmanship" to "lasting empathy". Upgrade. The project not only endows the cultural heritage with the new language of the era of Cyber, but also integrates resources with digital ecology, provides a practical sample of "content-driven technology" for the

transformation of the industry, puts into practice the national strategy of cultural digitization, and establishes a scientific and technological bridge for the dialogue between ancient and modern civilizations.

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References

- [1] Li Yuting, Wu Qi, Liu Jiaxin, et al. Deep learning and three-dimensional reconstruction in ancient architecture surface damage detection[N]. Shanxi Science and Technology News, 2025-06-16(A07).
- [2] GARASEN, PEI Jiajie. Risk management of cultural heritage protection in the age of digital intelligence[J]. Cultural Heritage, 2025, 03: 60-67.
- [3] Zeng Lisan, Wu Lingxi, Liu Shugang, et al. Design and realization of laser presentation system based on vector graphics [J]. Laser and Infrared, 2016, 46(10): 1273 -1278.
- [4] Rao Yixiong. Protection and restoration methods of wooden structures of ancient buildings[J]. Sichuan Building Materials, 2024, 50(11): 48-50.
- [5] YAN Zhitao, HE Junlang, LIU Jie. Application research on ancient building restoration and protection and ancient and modern building coordination design and construction based on BIM+ technology[J]. Guangdong Civil Engineering and Architecture, 2024, 31(11): 4-7.
- [6] YUAN Xiaodong. New technology of ancient building repair provides path for in situ restoration[J]. Chinese Folk Habitat, 2024, 17(08): 46-47.
- [7] YANG YATIAN. Application of panoramic technology in the restoration of ancient buildings[J]. Foshan Ceramics, 2024, 34(01): 72-74.
- [8] YI Jiaying, GONG Caixin, SHI Yudong. Discussion on the Path of Intellectualized Protection and Live Inheritance of Intangible Cultural Heritage Empowered by Digital Technology[J]. Journal of Hubei University of Technology, 2025, 40(03): 58-61.
- [9] Chen Yiwei, Wu Xuebing. Digital Intelligence Technology Enabling the Inheritance of Chinese Excellent Traditional Culture: Era Value, Reality Coupling and Enhancement Strategy[J/OL]. Journal of North Central University (Social Science Edition), 1-8[2025-07-10].
- [10] BU Liyun. Research on Protection and Restoration Strategies of Ancient Buildings in China[J]. Collection, 2024, (05): 69-71.