Research on Protection of Cultural Heritage in Shandong Yellow River Basin in Digital Technology Era

Lixia Zhang[1,*], Zhongli Sun[2] and Xiaohua Zhang[2]

[1]Business College, Shandong Xiehe University, Jinan, China
[2]Aisino Corporation (Shandong), Aisino Corporation, Jinan, China
e-mail: 232312387@qq.com[*]; 273960475@qq.com; 420615182@qq.com

Abstract. This paper discusses the application and effect of digital technology in the protection of cultural heritage in the Yellow River Basin in Shandong Province. The research shows that technologies such as digital archive, virtual reality, augmented reality and big data analysis play an important role in the protection of cultural heritage. Through case studies, this paper shows the specific application of these technologies in the Yellow River Basin in Shandong Province, and puts forward the challenges and future development directions. The research results are of great significance for promoting the digital transformation of cultural heritage protection.

Keywords: digital technology; Yellow River Basin; Cultural heritage protection; Digital archiving; Virtual reality; Big data analytics

1   Introduction

As one of the birthplaces of Chinese civilization, the Yellow River Basin has rich and precious cultural heritage resources. As an important area in the lower reaches of the Yellow River, the Shandong section of the Yellow River has unique historical value and cultural significance. With the rapid development of digital technology, the protection methods of traditional cultural heritage are facing unprecedented opportunities for change. The purpose of this study is to explore the application status, effect and future development direction of digital technology in the protection of cultural heritage in the Yellow River Basin in Shandong Province, so as to provide theoretical basis and practical reference for the digital transformation of cultural heritage protection.

2   Overview of cultural heritage in the Yellow River Basin in Shandong Province

The Yellow River Basin in Shandong has rich and diverse cultural heritage resources, including material cultural heritage and intangible cultural heritage. In terms of material cultural heritage, there are many ancient sites, ancient buildings, grottos and stone carvings, such as the Dawenkou cultural site, Longshan cultural site and

other prehistoric civilization relics, as well as the Confucian cultural complex such as the Confucian temple and the Confucian mansion in Qufu. In terms of intangible cultural heritage, there are traditional skills, folk arts and folk activities, such as Lu embroidery, Shandong Wooden Clappers, Yellow River Haozi and other traditional performing arts[1].

These cultural heritages not only have important historical value and reflect the development of the civilization of the Yellow River Basin, but also contain rich cultural connotations and are important carriers of the cultural identity of the Chinese nation. At the same time, they also have significant tourism value and economic value, and are important resources to promote the development of local cultural industries. However, affected by natural erosion, man-made damage and other factors, these precious cultural heritages are facing different degrees of protection pressure.

3   The application of digital technology in cultural heritage protection

The application of digital technology in the field of cultural heritage protection is increasingly widespread, mainly including the following forms: digital archive technology realizes the digital record and preservation of cultural heritage through high-precision scanning, three-dimensional modeling and other means; Virtual reality (VR) and Augmented reality (AR) technologies can reconstruct historical scenes and provide immersive cultural experiences. Big data analysis technology can be used for the data management and value mining of cultural heritage.

In the Yellow River basin of Shandong Province, these technologies have been preliminarily applied. For example, 3D laser scanning technology has been used to digitally map the Confucian Temple complex in Qufu and establish accurate digital archives. VR technology is used to reproduce the life scene of Dawenkou culture period. Big data analysis was used to systematically study and classify the intangible cultural heritage of the Yellow River Basin. These applications not only improve the efficiency and accuracy of cultural heritage protection, but also expand new ways of public participation and cultural communication.

4   Specific application cases of digital technology in the protection of cultural heritage in the Yellow River Basin in Shandong Province

In the protection practice of cultural heritage in the Yellow River Basin in Shandong province, the innovative application of digital technology has achieved remarkable results, which has opened up a new path for the protection and inheritance of material cultural heritage and intangible cultural heritage. The application of these technologies not only improves the scientificity and accuracy of the protection work, but also greatly expands the scope of cultural heritage communication and public participation.

4.1   Digital protection of material cultural heritage: Take the Confucian Temple complex as an example

As a world cultural heritage, the protection of the Confucian temple complex in Qufu, Shandong province has special significance. In recent years, led by the Shandong Provincial Administration of Cultural Heritage, the School of Architecture of Tsinghua University and the top digital technology enterprises in China have jointly carried out a comprehensive digital protection project of the Confucian temple building complex[2]. The project uses today's most advanced 3D laser scanning technology and professional equipment such as Leica ScanStation P40 to collect 3D data with millimetre-level accuracy for core buildings such as Dacheng Hall, Kuiwen Pavilion and the Pavilion of 13 steles.

The technical team used multi-site cloud stitching technology in the scanning process to ensure the integrity of the overall data of the building. The data collection density of each scanning site reaches thousands of points per square meter, which can accurately record the subtle features of the building surface, including the mortise and tenon structure of wood components, the texture details of stone carvings, etc. After professional processing, a complete Building Information Model (BIM) is established, which not only contains geometric information, but also integrates multi-dimensional data such as building materials and structural performance.

This digitized achievement has played multiple roles in practical conservation work. First, it provides an unprecedented level of precision for building restoration. For example, in the 2022 roof maintenance project of Dachan Hall, technicians accurately found the 0.8mm deformation of wood members by comparing the scanning data over the years, and took timely reinforcement measures. Secondly, the virtual display platform developed based on these data enabled the global audience to "travel" the Confucius Temple through the network, and the number of visits during the epidemic exceeded one million. What is more worth mentioning is that these digital archives also provide a reliable guarantee for possible reconstruction work in the future, ensuring the continuity of the authenticity of cultural heritage.

4.2   Digital inheritance of intangible cultural heritage: Yellow River Haozi protection Project

As a unique labor ballad of the Yellow River Basin, "Yellow River Haozi" was included in the national intangible cultural heritage list in 2008. However, with the development of modern shipping technology, there are less than ten old artists who have mastered this art, and the rescue protection is imminent. Shandong Intangible Cultural Heritage Protection Center and China Conservatory of Music have launched the "Yellow River Haozi Digital Protection Project".

The project uses the international leading panoramic sound recording technology, in the east Ming, Juancheng and other traditional dock along the Yellow River, set up a professional recording studio, recorded the complete singing of 7 representative heritage. The recording adopts a high sampling rate of 192kHz/32bit, which completely retains the overtone column and spatial information in the singing. At the same time, the Vicon motion capture system was used to record the body language and labor movements during singing, and a multimedia database containing audio, video and three-dimensional movement data was formed.

Based on these data, the technical team developed a variety of digital display methods. AR is the most compelling interactive applications "Yellow River", by the user mobile scanning a particular pattern, can see the virtual image of the old waterman, heard the original song to sing, can also interact with the learning[3]. The application of on-line within one year, downloaded over 500000 times, 70% of users for the young people under the age of 30. In addition, the project team also used the collected data for AI analysis and successfully decoded the correspondence between singing and labor rhythms, providing a new perspective for studying the shipping history of the Yellow River.

4.3   Digital integration of cultural resources: A knowledge map of cultural heritage in the Yellow River Basin

In order to break the "information island" phenomenon of cultural heritage data, Shandong University and a number of research institutions have built a "knowledge map of cultural heritage in the Yellow River Basin" for three years. The program integrates the coast of shandong section of the Yellow River more than 500 points[4] of the cultural heritage data, including archaeological sites, ancient architectural structures, intangible cultural heritage and other kinds of resources.

The technical team used big data analysis methods to process the massive documents, archaeological reports and image records in a structured way. Through natural language processing technology, entities (such as people, events, places) and their relationships in the text are automatically extracted, and a knowledge network containing more than 200,000 nodes[5] is constructed. The most prominent feature of this system is the intelligent association of cross-domain data. For example, when a user queries a historical figure, the system will automatically present information such as sites, cultural relics, and folk activities related to it.

Knowledge graph has shown great value in practical applications. In the Yellow River flood control work in 2023, the system accurately predicted the possible inundate risk of three ancient sites by analyzing historical hydrological data and site distribution, which saved valuable time for rescue work. In addition, this system also provides data support for decision-making such as cultural tourism route planning and cultural relic protection priority assessment.

5   Real Challenges and Optimization Paths

5.1 Technical Adaptability Bottleneck

The large-scale application of digital technology in the protection of cultural heritage faces significant challenges. There is a sharp contradiction between the high cost and the demands of grassroots units. The initial investment in the digital tour guide system of the Dongshan Baiyuan reached 3 million yuan, far exceeding the budget capacity of county-level cultural relic protection units. At the same time, the problem of technical applicability is prominent. The dizziness rate of some VR devices exceeds 15%, which has a negative impact on the experience of the elderly. These phenomena reflect the structural contradictions in the promotion of digital technology: most cutting-edge technologies are developed by universities or technology enterprises, lacking sufficient consideration of the actual needs and user charac-

teristics of grassroots cultural relic protection units.

To address this predicament, it is necessary to explore lightweight technical solutions and innovative collaboration mechanisms. The "basic service free + value-added service revenue generation" model adopted by Heze Unicom in the construction of the smart cultural relics supervision platform offers a valuable reference. The government purchases basic monitoring services to ensure the safety of cultural relics, while opening up data analysis capabilities to support tourism development, forming a sustainable operation loop. At the technical design level, efforts should be made to promote the development of "age-friendly digital interfaces", such as the Qufu "Digital Confucian Temple" project, which simplifies the AR operation process and lowers the usage threshold through voice interaction. Additionally, establishing a provincial digital technology sharing platform to centrally purchase high-cost software licenses (such as 3D modeling tools and AI analysis systems) and provide inclusive technical support to county-level cultural relics protection institutions can effectively lower the threshold for technology application and avoid redundant resource investment.

5.2 Imbalance in Living Transmission

The application of digital technology in the inheritance of intangible cultural heritage (ICH) has sparked controversy over the "de-embodiment of skills", highlighting the deep tension between technological empowerment and cultural authenticity. Research data shows that the average age of ICH inheritors in villages along the Yellow River is 62 years old, and only 28% of them are proficient in digital tools, posing a serious risk of intergenerational gap. The AI paper-cutting system developed by Shandong Business Vocational College, although it has improved the efficiency of creation, has raised questions about "machines replacing manual work". Some inheritors are concerned that the simplification brought by technology may weaken the cultural connotations and emotional values contained in paper-cutting skills. This controversy essentially reflects the value conflict between "efficiency" and "authenticity" in ICH protection.

Establishing a "dual-track inheritance mechanism" is an effective way to balance the contradictions. The practice of Liujin County paper-cutting protection provides a demonstration: on the one hand, inheritors record technique teaching videos through VR and establish a digital knowledge base; on the other hand, the "handmade warmth" experience is retained in the intangible cultural heritage workshop, and trainees need to complete 300 hours of offline practice to obtain certification. The "university + workshop + community" collaborative model proposed by Sanya University in the research of Hainan intangible cultural heritage is also applicable to the Shandong scenario - universities are responsible for technology research and development and digital archiving, workshops focus on skill transmission, and communities provide cultural context and application scenarios, forming an organic unity of technological empowerment and cultural root protection. This model not only respects the dynamic evolution law of intangible cultural heritage but also ensures that core skills are not deconstructed by technology, achieving a balance between instrumental rationality and value rationality.

5.3 Challenges of Sustainable Management

The digitalization of cultural heritage is confronted with structural predicaments such as "data silos" and the absence of long-term operational mechanisms. According to statistics, the annual update rate of content in 75% of county-level digital museums is less than 10%, and the data standards of various platforms are not unified, making resource sharing difficult. The research on "The System Construction of the Shandong Section of the Yellow River National Cultural Park" points out that the current lack of cross-regional and cross-departmental coordination and linkage mechanism platforms leads to poor circulation of some data, information, and resources, making it difficult to achieve resource sharing. In addition, digital projects overly rely on short-term special funds and lack sustainable operation models, resulting in a common phenomenon of "emphasizing construction but neglecting maintenance".

To break this deadlock, both institutional innovation and technological architecture need to advance in parallel. At the provincial level, a meta-database for cultural heritage can be built on the "Shandong Public Culture Cloud" platform, and unified standards for the collection, storage and exchange of digital resources can be formulated to break down the resource barriers among the provincial, municipal and county levels. In terms of management mechanisms, the experience of the "Monitoring - Research - Protection - Exhibition - Management" integrated platform of the Dunhuang Research Institute can be drawn upon to establish a digital archive management system covering the entire river basin. At the same time, a "digital transformation revenue feedback" mechanism can be explored. For instance, Qingdao Institute of Technology authorized a cultural and creative enterprise to use the digital model of Lu Jin, and the revenue was used to support the training of intangible cultural heritage inheritors, forming a virtuous cycle. Through institutional design, the continuous update and value release of digital assets can be ensured, and the technological investment can truly be transformed into a long-term driving force for the protection of cultural heritage.

5.4   Looking forward: Towards the integration of digital twins and the metaverse

While technology is evolving, more attention should be paid to the reconstruction of social values. The protection of cultural heritage in the digital age should go beyond the technology-oriented approach and move towards a coordinated development of "technology - humanity - ecology". On the one hand, by establishing "community digital workshops", the cultural identity of residents can be enhanced. For instance, in the protection of the canal culture in Yanggu County, local residents were trained to use their mobile phones to scan and collect folk custom data, making them the main participants in cultural digitalization. On the other hand, develop the ethical framework of "responsible innovation", introduce the mechanism of authorship rights and copyright dividends for inheritors in AI-generated paper-cutting projects, and ensure the fair sharing of technological dividends Only by integrating technological logic with humanistic care can the digital Yellow River become a living source that nourishes cultural innovation and promote the fine traditional Chinese culture to shine with new luster in the era of digital civilization.

Digital technology has injected revolutionary impetus into the protection of cultural heritage in the Yellow River Basin of Shandong Province. From the AI tour guide in Dongshan Baiyuan to the intelligent monitoring of cultural relics in Heze, from the

virtual simulation of Lu brocade to the digital dissemination of Lijin paper-cutting, technology is profoundly reshaping the protection logic and inheritance paradigm of cultural heritage. This paper's research shows that digital technology has demonstrated significant advantages in building a gene bank of cultural heritage, innovating dynamic display methods, and achieving intelligent monitoring and management, providing a brand-new solution for addressing the challenges of natural erosion and humanistic inheritance.

6   Conclusions

Digital technology provides new ideas and methods for the protection of cultural heritage in the Yellow River Basin in Shandong province, and shows unique advantages in improving protection efficiency, expanding the scope of communication, and enhancing public participation. However, in order to realize the deep integration of digital technology and cultural heritage protection, it is still necessary to overcome various obstacles such as technology, capital, talent and management. Future research should further explore the application of digital technology in the fields of cultural heritage value mining, inheritance and innovation, and pay attention to the issues of technology ethics and cultural safety, so as to promote the sustainable development of cultural heritage protection.

References

1. Zhang Mingyuan, Li Wenhua. Theory and Method of Digital Cultural Heritage Protection. Cultural Relics Press, 2020.
2. Wang Jing, Liu Keji. Application Research of three-dimensional digital technology in the protection of ancient Architecture. Chinese Cultural Heritage, 2019(3): 45-52.]
3. Chen, L., & Smith, J. "Digital Preservation of Intangible Cultural Heritage: A Case Study of Traditional Performing Arts". Journal of Cultural Heritage, 2021, 28(2): 134-145.
4. Yellow River Culture Research Institute. Investigation Report of Cultural Heritage Resources in the Yellow River Basin. Shandong University Press, 2018.
5. Zhao Chuangxin, Sun Geng. "A new model of Cultural heritage protection in the era of Big Data ". Cultural Heritage Protection and Archaeological Science, 2022, 34(1): 78-86.
6. Li Wei, Zhang Yating."3D Digital Reconstruction Technology in the Conservation of Yellow River Historical Sites: A Case Study of Shandong Section".Journal of Digital Landscape Architecture, 2023, 8(2): 45-58.
7. Chen Xu, Wang Feng."AI-Driven Revitalization of Intangible Cultural Heritage Along the Yellow River Basin: Challenges and Pathways".International Journal of Heritage Studies, 2021, 27(4): 392-407.
8. Smith J.A., Liu Hong."Smart Monitoring Systems for Flood-Prone Cultural Heritage: Lessons from the Lower Yellow River".Sustainability, 2024, 16(3): 1125-1140.
9. Shandong Provincial Institute of Cultural Relics and Archaeology."Integrating Metaverse Technology into the Interpretation of Confucian Cultural Heritage: The Qufu Pilot Project".Virtual Archaeology Review, 2023, 14(1): 29-41.
10. Yang Rui, Zhao Lin."Digital Storytelling and Tourism Experience Design: Revitalizing Cultural Heritage Along the Shandong Yellow River Corridor".Journal of Sustainable Tourism, 2023, 31(7): 1583-1601.

11. Garcia M., Li Xiaoyu."Community-Driven Digital Archives: A New Paradigm for Safe-guarding Intangible Heritage in Rural China".International Journal of Intangible Heritage, 2024, 19: 112-128.