Research on the Strategy of Digital Empowerment for the Integrated Development of Yellow River Culture

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Abstract: In the context of rapid development of the digital economy, the Yellow River culture, as an important carrier of Chinese civilization, faces the dual challenges of lagging inheritance methods and insufficient dissemination efficiency. At present, there are prominent problems with the lack of digital standards, loose industrial chains, and single dissemination channels in the cultural resources of the Yellow River, which make it difficult to form a synergistic effect between cultural heritage protection and innovative utilization. This article focuses on the research perspective of reconstructing the cultural production paradigm based on digital technology. Starting from the construction of a systematic strategic framework of "data governance scene creation business innovation", the article proposes implementation paths such as establishing a cultural gene database in the Yellow River Basin, developing immersive cultural experience products, and cultivating digital creative industry clusters. Research has shown that blockchain technology can effectively solve the problem of cultural property rights, virtual reality technology can break through geographical limitations and activate historical scenes, and artificial intelligence assisted technology can provide innovative momentum for cultural content production. The deep integration of digital civilization and traditional culture has not only given rise to new cultural formats, but also achieved the dynamic inheritance of cultural heritage through the construction of a symbiotic cultural ecosystem between reality and virtuality. Through digital research, cultural dimension practical references have been provided for the national strategy of ecological protection and high-quality development in the Yellow River Basin, which has practical guiding significance for promoting the transformation and upgrading of regional cultural industries.

Keywords: Digital Empowerment; Yellow River Culture; Blockchain Technology; Immersive Communication; Digital Ecosystem

1. The Era Value and Research Framework of Yellow River Culture Inheritance in the Digital Age

The rapid development of digital technology has opened up a new path for the protection of traditional culture. The Yellow River culture, as a spiritual symbol of Chinese civilization, has three core values in its inheritance in contemporary times: firstly, digital means break through physical space limitations, enabling immovable cultural relics such as the Longmen Grottoes to be permanently preserved in the cloud, and preserving precious cultural memories for future generations; Secondly, virtual reality technology revitalizes historical scenes, allowing legends such as Yu the Great's flood control to gain recognition from young people through immersive experiences; Finally, the construction of the cultural gene database promotes the formation of a cultural community consciousness in the 9 provinces and regions within the Yellow River Basin, laying a spiritual foundation for the high-quality development of the Yellow River Basin.

In terms of theoretical framework construction, the research follows the logical chain of "value recognition mechanism analysis path design". By sorting out the digital symbol system of the Yellow River culture, extract core images with dissemination value; Using digital twin technology to establish a dynamic map of cultural resources, revealing the connection mechanism between cultural heritage and contemporary society; Ultimately, a three-dimensional strategy model will be formed,

which includes building the foundation of data governance, empowering scene experience, and driving business innovation. Among them, blockchain technology solves the problem of confirming the ownership of intangible cultural heritage skills, artificial intelligence assists in the creation of new cultural products such as digital collections, and the cross regional collaboration platform supported by 5G network promotes the sharing of cultural resources[1].

This research framework emphasizes the deep integration of technological applications and cultural connotations, focusing not only on the innovation of cultural expressions through digital tools, but also on exploring the spiritual inheritance value of traditional culture empowered by technology. By constructing a cultural ecosystem of virtual and real coexistence, a systematic solution has been provided to resolve the contradiction between heritage protection and innovative development.

2. Analysis of the Current Situation of Digital Integration And Development of Yellow River Culture

2.1 Application Map of Digital Technology in the Protection of Yellow River Cultural Heritage

In the practice of protecting the cultural heritage of the Yellow River, digital technology has formed a multidimensional application system. Through 3D laser scanning and drone oblique photography technology, immovable cultural relics such as Longmen Grottoes have achieved millimeter level precision modeling. Their digital achievements not only provide accurate data support for restoration projects, but also break through physical exhibition limitations through cloud display[2]. The application of AR technology has been validated in the Zhengzhou Shang Dynasty Ruins Park, where visitors can watch virtual restoration scenes of rammed earth city walls through their mobile phones. This virtual and real overlay presentation significantly enhances the readability of cultural heritage.

In the field of digital restoration, deep learning algorithms have demonstrated unique value. For the oracle bone fragments of Yin Xu in Anyang, the artificial intelligence assisted splicing system has improved the efficiency of traditional restoration by nearly ten times through feature point matching. The inheritors

of Kaifeng Bian embroidery intangible cultural heritage use motion capture devices to transform embroidery techniques into standardized digital tutorials, which not only solves the problem of intergenerational loss in skill inheritance, but also reserves a dynamic material library for cultural and creative product development. The introduction of blockchain technology effectively guarantees the copyright ownership of digital assets. The digital Tang Sancai collection developed by the Luoyang Museum is confirmed and traded through smart contracts, creating a new model for the development of digital derivatives of cultural relics.

The currently formed application graph presents three significant features: achieving standardized processing of multi-source heterogeneous cultural resources at the data collection layer, constructing a virtual real linkage cultural interpretation system at the content development layer, and forming a full chain solution covering protection, restoration, display, dissemination, and innovative utilization at the service application layer. This technology integration application mode provides systematic tool support for resolving the contradiction between cultural heritage protection and revitalization utilization.

2.2 Bottleneck Analysis of Digital Transformation of Cultural and Tourism Industry in the Yellow River Basin

In the process of digital transformation of the cultural and tourism industry in the Yellow River Basin, there are still multiple structural obstacles that constrain its development efficiency. Firstly, the uneven construction of digital infrastructure is prominent. Although core scenic spots such as Longmen Grottoes have achieved 3D modeling and virtual display, most small and medium-sized cultural venues in the basin still lack basic data collection equipment, making it difficult to form standardized digital assets for precious cultural relics resources. This digital divide not only causes fragmentation in the development and utilization of cultural resources, but also makes it difficult for cross regional cultural and tourism projects to achieve data exchange and resource sharing.

There is a disconnect between technological applications and industrial demands. Currently, virtual reality, blockchain and other technologies are mostly concentrated in the

display stage, and have not effectively penetrated into the core links of the value chain such as cultural and creative product development and cultural tourism service upgrading. The tripartite cooperation mechanism between the government, enterprises, and scenic spots is not yet sound, resulting in insufficient matching between technology supply and market demand. Some digital experience projects tend to prioritize form over content, and tourist participation and revisit rates have not achieved the expected results.

Furthermore, the shortage of versatile talents constrains the depth of digital transformation. The insufficient reserve of cross-border talents who are proficient in both digital technology and cultural connotations has resulted in the development of digital content mostly staying at the level of superficial symbol transplantation, making it difficult to deeply explore the spiritual core of Yellow River culture. Cultural and tourism enterprises rely heavily on external team support in key technological fields such as motion capture and artificial intelligence creation, with weak independent innovation capabilities, which affects the sustainable promotion of digital transformation.

The regional collaborative governance mechanism is not yet perfect. The nine provinces and regions in the Yellow River Basin lack unified norms in data standards, copyright management, and revenue distribution, resulting in a "data island" effect. Although some regions have piloted the construction of digital resource libraries, it is difficult to achieve the integration and utilization of cross regional cultural resources due to inconsistent technical standards and inadequate sharing mechanisms. This administrative division state conflicts with the open and shared characteristics required by the digital economy, which restricts the overall competitiveness of the cultural and tourism industry in the basin.

3. A Multidimensional Strategic System of Digital Empowerment for the Integrated Development of Yellow River Culture

3.1 Path for Cultural Resource Ownership and Sharing Based on Blockchain Technology

The application of blockchain technology in the management of Yellow River cultural resources provides innovative solutions to long-standing ownership disputes and resource sharing challenges. Under the traditional mode, the ownership registration of cultural elements such as intangible cultural heritage skills and cultural relics digital assets relies on manual review, which leads to complex processes and long confirmation cycles, making it difficult to effectively transfer a large amount of cultural resources. By building a blockchain based distributed ledger system, the full lifecycle traceability of cultural resources can be achieved, and creators, inheritance institutions, users, and other entities can be included in a trusted collaborative network. This technological feature is particularly suitable for collaborative management of cross regional cultural resources.

In terms of innovative mechanisms for property rights confirmation, we will focus on breaking through two major areas: identity authentication of intangible cultural heritage inheritors and digital copyright protection. For the traditional skills such as Paper Cuttings and clay sculpture in the Yellow River basin, a smart contract system including biometric identification and creation track recording is established. When the inheritor completes the digital transformation of the work, the system automatically generates electronic credentials containing timestamps and creative feature codes, which are permanently stored on the blockchain node through hash encryption. This tamper proof method not only safeguards the legitimate rights and interests of the inheritor, but also provides a clear ownership basis for the subsequent development of derivative products.

The construction of a resource sharing system focuses on addressing the challenges of regional collaborative governance. Building a cultural data platform for the Yellow River Basin based on alliance chain technology, connecting digital resource libraries of museums and intangible cultural heritage protection centers in various provinces and cities. By formulating smart contract rules, clarify the data access permissions and benefit distribution mechanisms for nodes at different levels. For example, the secondary development income of digital Tang Sancai collections can be automatically allocated to copyright holders, technology providers, and operation platforms according to the preset proportion of smart contracts. This decentralized management model effectively breaks down trust barriers in

cross administrative collaboration.

Typical application scenarios have formed a demonstration effect within the watershed. In the Kaifeng Bianxiu digital protection project, the blockchain system fully records the digital collection process of 82 traditional needlework techniques, ensuring the originality certification of every technical detail. The cultural relic digital asset trading platform established in Luoyang achieves full process automation management of collection rights confirmation, authorized use, and revenue sharing through smart contracts, significantly improving the efficiency of cultural resource conversion. These practices demonstrate that the immutability and transparency features of blockchain technology are reconstructing the trust foundation for the development and utilization of cultural resources.

3.2 Application Practice of Digital Twin Technology In Heritage Protection

The digital twin technology provides a governance paradigm of virtual real mapping for cultural heritage protection, and its core value lies in building a real-time interactive system between physical entities and digital models. In the practice of cultural heritage protection in the Yellow River Basin, this technology has formed a full cycle protection chain of "data collection digital modeling monitoring and warning decision optimization" through high-precision 3D modeling, multi-source data fusion, and dynamic simulation, effectively solving pain points such as data discontinuity and intervention lag in traditional cultural relic protection.

In the digital protection of immovable cultural relics, the collaborative application of LiDAR and oblique photography technology has achieved millimeter level accuracy modeling of ancient architectural complexes and site landforms. Taking the Longmen Grottoes in Luoyang as an example, by establishing a digital twin that covers rock structure, environmental parameters, and disease characteristics, the cultural relic protection team can monitor the impact of microclimate on stone carving weathering in real time and simulate the intervention effects of different protection schemes. This virtual rehearsal mechanism shifts cultural relic protection from passive rescue to active prevention, significantly enhancing the scientificity of intervention decisions. For movable cultural relics, digital twin technology reconstructs intangible cultural genes such as bronze casting technology and porcelain firing process through material spectrum analysis and dynamic stress simulation, breaking through the limitations of experience dependence in cultural relic restoration.

At the level of overall protection of heritage sites, the digital twin platform connects to the Internet of Things sensor network to build a cross temporal and spatial heritage monitoring system. The practice of Kaifengzhou Bridge Site shows that by deploying intelligent sensors such as vibration, temperature and humidity, and crack displacement, the impact of groundwater level changes on the site can be captured in real time. When the monitoring data deviates from the preset threshold, the system automatically triggers a warning and generates a multi scenario protection plan. This intelligent response mechanism greatly enhances the ability of heritage sites to resist natural erosion and human damage, providing technical support for the coordinated protection of large-scale linear cultural heritage in the Yellow River Basin.

The innovative application of technology has simultaneously reshaped the modes of heritage display and public participation. The Zhengzhou Dahucun Site Museum uses a digital twin system to superimpose archaeological excavation sites and virtual restoration scenes in time and space. After wearing mixed reality devices, the audience can not only observe the excavation status of cultural relics in the real exploration area, but also immerse themselves in the virtual scene of ancient pottery making and cultivation six thousand years ago. This fusion of virtual and real display method breaks through the physical limitations of traditional exhibitions, transforming the process of protecting cultural heritage into a perceptible carrier of cultural dissemination. More importantly, the audience interaction data collected by the system continuously feeds back into the optimization of the digital model, forming a virtuous cycle of protection and activation.

The technical implementation of cross regional collaboration mechanisms is the deep value of digital twin applications. By constructing a digital platform for cultural heritage in the Yellow River Basin, key cultural relics data from nine provinces and regions along the Yellow River can be standardized and

visualized. During the 2022 Yellow River autumn flood season, the platform successfully alerted three endangered sites and determined the optimal rescue path through digital twin simulation. This technology driven collaborative protection model provides innovative solutions for breaking down protection barriers caused by administrative division, marking a new stage of digital governance for the protection of cultural heritage in the Yellow River Basin.

3.3 Mechanism Construction of Immersive Dissemination of Yellow River Culture in the Metaverse Scenario

Under the framework of metaverse technology, the dissemination of Yellow River culture is breaking through the limitations of traditional models and forming a new communication paradigm that blends reality and virtuality. By constructing three-dimensional digital twin scenes, cultural heritage sites such as Longmen Grottoes and Yin Ruins can be accurately restored in virtual space. With the help of VR devices, viewers can freely switch observation perspectives and perceive architectural details and historical context from multiple dimensions. This immersive experience breaks through the physical limitations of physical exhibitions, allowing audiences thousands of miles away to participate in online cultural exploration activities in real time, significantly enhancing the coverage of cultural dissemination.

At the technical implementation level, the focus is on establishing a multimodal interaction mechanism. Using spatial computing technology to integrate Yellow River hydrological data with cultural symbols, an interactive virtual water management project experience has been developed. Tourists can manipulate virtual dams through gestures to intuitively understand the historical evolution of Yellow River control wisdom such as "water and sand regulation". At the same time, the user generated content (UGC) model is introduced to encourage participants to create digital Paper Cuttings, virtual clay sculptures and other cultural works on the meta universe platform. After blockchain ownership confirmation, an open cultural resource library is formed to stimulate the initiative of the public to participate in cultural communication.

In terms of optimizing communication efficiency, we will build an intelligent recommendation system. By analyzing the user's behavior trajectory and duration of stay in the virtual scene, artificial intelligence algorithms automatically match cultural commentary content. For example, in the virtual Kaifeng Qingming Riverside Scene, tourists interested in architecture will trigger an animated analysis of mortise and tenon structures, while users interested in commercial elements will receive an explanation of the currency system of the Song Dynasty. This adaptive dissemination mechanism makes cultural interpretation more targeted and attractive.

Cross platform collaboration mechanism is the key to ensuring the continuity of dissemination. Integrate digital resources of museums with real-life data of cultural and tourism attractions, and build a metaverse entrance that supports multi terminal access. After visiting Zhengzhou on site, tourists can continue to explore virtual extension scenarios through their mobile devices, achieving seamless integration of online and offline experiences. The cultural management department relies on this platform to carry out cross regional exhibitions, linking the characteristic cultures of different sections of the Yellow River Basin into themed roaming routes, forming a scale effect of cultural dissemination.

4. Prospects for the Ecological Reconstruction of Yellow River Culture from the Perspective of Digital Civilization

In the wave of digital civilization development, the cultural ecology of the Yellow River is undergoing systematic reconstruction. This kind of reconstruction is not simply a digital transplant of traditional culture, but a new ecosystem that promotes the recombination of cultural elements through technological innovation, forming a symbiotic relationship between reality and virtuality. Currently, the popularization of 5G network and IoT technology enables real-time perception and dynamic connection of cultural resources in the Yellow River Basin, laying the technical foundation for building a comprehensive cultural data graph.

The core of cultural ecological reconstruction lies in establishing a multi-party collaborative mechanism. The government, technology companies, cultural institutions, and the public form an innovative community to jointly participate in the digital development of cultural resources. For example, in the field of intangible cultural heritage inheritance, traditional skills of

old artists are recorded through motion capture devices, and standardized teaching data is generated by combining artificial intelligence algorithms, which not only preserves the essence of skills but also improves dissemination efficiency. This collaborative model breaks the previous situation of each working independently, forming a virtuous cycle of resource complementarity and value sharing.

In terms of application scenarios, the integration of virtual and real cultural experience space has become an important development direction. The virtual historical district replicated by digital twin technology not only fully displays the urban style of Kaifeng's Song capital, but also allows tourists to interact with virtual vendors through AR devices. This folding presentation of time and space transforms static cultural heritage into participatory life scenes, effectively enhancing the cultural identity of young people.

The future cultural ecology will exhibit dynamic evolutionary characteristics. By building an open digital creation platform, we encourage the public to engage in secondary creation of Yellow River cultural elements. Blockchain technology ensures the intellectual property rights of original creators, and artificial intelligence assisted tools lower the threshold for creation, ultimately forming a cultural production system that combines official protection and folk innovation. This ecological model can maintain the purity of cultural genes and stimulate the vitality of continuous innovation.

The technological driven cultural ecological reconstruction is changing the traditional paradigm of inheritance. The cloud computing platform integrates dispersed cultural data resources, and intelligent algorithms mine the inherent relationships between cultural symbols, forming a self updating cultural knowledge network. This transformation not only enhances the effectiveness of cultural dissemination, but more importantly, establishes a deep connection between traditional culture and modern life, injecting new sustainable development momentum into the Yellow River culture.

Acknowledgements

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