

Research on the Evolutionary Path and Future Trends of Empowering the Digital Cultural Industry with Artificial Intelligence

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Abstract

With continual breakthroughs in artificial intelligence (AI) technologies and the expansion of their application scenarios, the digital cultural industry is undergoing an evolutionary process from basic informatization support to deep intelligent integration. This paper first reviews the current state of AI development and the evolution of the digital cultural industry, then explores the enabling roles of AI in two key stages— the Informatization Support Period and the Intelligent Integration Period. Through in-depth analysis of representative application cases—intelligent content creation and recommendation, virtual reality and immersive experiences, digital museums and cultural heritage preservation, and digital performance and virtual idols—this study reveals how technology drives transformations in industry models, user experiences, and value chains. Finally, it looks ahead to AI’s future development in algorithmic innovation, multimodal interaction, ecosystem collaboration, and policy governance, and offers countermeasures for challenges such as data security, copyright protection, and talent cultivation. The research aims to provide government, industry, and academia with a systematic theoretical framework and practical roadmap to support the high-quality, sustainable development of the digital cultural industry.

Keywords

Artificial Intelligence; Digital Cultural Industry; Evolutionary Path; Immersive Experience.

1. Introduction

Driven by rapid advances in information technology, the digital cultural industry has become a vital vehicle for cultural dissemination and the creative economy. In recent years, next-generation technologies represented by AI have achieved major breakthroughs in image recognition, natural language processing, recommendation algorithms, and virtual reality, profoundly reshaping the production, distribution, and consumption of digital content. Yet in practice, challenges remain: fragmented technology silos, severe homogeneity of application scenarios, and insufficient coordination across the value chain. Traditional digital cultural products rely largely on single-mode informatization and fail to meet users’ demands for personalized, immersive, multi-sensory interaction. Meanwhile, many enterprises and cultural institutions limit AI adoption to small-scale pilots, lacking a systematic evolutionary path or guiding framework—resulting in wasted resources and stalled innovation. Therefore, it is imperative to comprehensively map out the stage-specific characteristics and intrinsic mechanisms by which AI empowers the evolution of the digital cultural industry, so as to offer an actionable roadmap for both practitioners and scholars. Positioned at the intersection of AI and the digital cultural industry, this study seeks to construct a systematic research framework of “Evolutionary Path–Practical Applications–Future Trends,” filling the gap in existing literature regarding the classification of industry evolution stages and analysis of driving

mechanisms. Theoretically, by deeply analyzing the Informatization Support Period and Intelligent Integration Period, the study enriches dynamic evolution theories of cultural industry digital transformation. Practically, through case studies on intelligent content creation, VR immersive experiences, digital museum preservation, and virtual idols, it distills replicable strategies and models to inform government policy-making and enterprise innovation roadmaps. The study's key innovations lie in: (1) proposing for the first time an AI-empowerment framework based on a two-stage evolutionary perspective; (2) revealing the mechanisms by which technology applications reconstruct the industry value chain through multimodal case comparisons; and (3) systematically outlining future trends and response strategies across three dimensions—algorithmic innovation, ecosystem collaboration, and policy governance—thereby offering forward-looking guidance for the sustainable, high-quality development of the digital cultural industry.

2. Theoretical Foundations and Literature Review

2.1. Overview of Artificial Intelligence Technologies

Since the “Turing Test” was proposed in the 1950s, artificial intelligence (AI) has undergone multiple paradigm shifts—from symbolic AI to statistical learning, and then to deep learning. Early research focused on rule-based expert systems and logical inference, aiming to simulate human expert decision-making via knowledge bases and inference engines. However, the high cost of knowledge acquisition and the difficulty of system maintenance limited symbolic AI's practical applicability. In the 21st century, with advances in computing power and access to large volumes of data, traditional machine learning algorithms—such as support vector machines, decision trees, and ensemble methods—gained widespread adoption[1]. Thereafter, deep learning models represented by convolutional neural networks (CNNs) and recurrent neural networks (RNNs) achieved breakthrough performance in image recognition, speech recognition, and natural language processing, becoming the dominant technology path in AI research and applications. From a technical standpoint, AI primarily encompasses the following areas:

Machine Learning and Deep Learning: Machine learning focuses on automatically learning mappings from data, with classic algorithms including linear regression, support vector machines, decision trees, and random forests. Deep learning employs multi-layer neural networks for end-to-end training; CNNs excel at visual perception tasks, while Transformer-based models (e.g., BERT, GPT series) lead in natural language understanding and generation.

Natural Language Processing (NLP): NLP methods—such as tokenization, word embeddings, and attention mechanisms—enable semantic representation and contextual understanding of text, supporting tasks like text classification, sentiment analysis, machine translation, summarization, and dialogue systems. The advent of pretrained language models has greatly enhanced few-shot learning and transfer learning capabilities, driving applications in intelligent writing and customer service[2].

Computer Vision (CV): CV techniques—including image processing, object detection, image segmentation, and 3D reconstruction—allow automatic recognition and interpretation of images and video. In the cultural domain, CV supports digital image restoration, artifact recognition, and structured annotation, underpinning digital museums and virtual exhibitions.

Knowledge Graphs and the Semantic Web: Knowledge graphs model large-scale domain knowledge through entities and relationships, facilitating intelligent knowledge retrieval, question answering, and reasoning. Semantic web technologies enable interconnection and interoperability of heterogeneous data in web environments, laying the groundwork for cross-platform, multi-source data integration.

Augmented Reality (AR) and Virtual Reality (VR): AR/VR combines AI algorithms with 3D graphics rendering and sensor fusion—using spatial tracking, gesture recognition, and real-time rendering—to create immersive interactive experiences[3]. When augmented by AI-

based scene perception and behavior prediction, these technologies deliver highly personalized cultural experiences. The popularization of open-source deep learning frameworks (e.g., TensorFlow, PyTorch) and cloud AI services (e.g., Model Zoo, cloud providers' AI platforms) has enabled researchers and developers to conduct algorithm validation and application deployment at lower cost and in shorter timeframes. Emerging paradigms such as edge computing and federated learning are shifting AI from "cloud-based training and inference" toward "cloud-edge collaboration and on-device intelligence," making real-time AI experiences on mobile, embedded, and IoT devices feasible. Nonetheless, challenges remain in data privacy protection, model interpretability, and balancing compute requirements with energy consumption—key directions for future AI applications in the digital cultural industry[4].

2.2. Current Status of the Digital Cultural Industry

In recent years, the digital cultural industry has experienced sustained high-speed growth, propelled by widespread internet access and mobile device adoption. According to the Ministry of Culture and Tourism, by 2023 China's digital cultural industry had surpassed one trillion RMB in scale, with an average annual growth rate exceeding 20%, making it the fastest-growing segment of the cultural sector. The industry encompasses digital publishing, online audiovisual content, gaming, digital creative design, virtual performances, and digital museums, forming a complete ecosystem from content production and technical support to distribution channels. On the consumer side, rising demand for personalized, immersive, multi-sensory experiences has fueled new formats such as short videos, immersive theater, cloud exhibitions, and digital collectibles. On the production side, traditional cultural institutions and creative enterprises have leveraged cloud computing, big data, and VR to explore new pathways in artifact digitization, intangible cultural heritage preservation, and digital art creation—reconstructing and redistributing content value[5]. At the same time, the industry exhibits both regional clustering and platformization. Innovation hubs in Beijing, Shanghai, Guangzhou, and Shenzhen have coalesced around leading digital entertainment platforms, specialized digital creative parks, and cultural-tech incubators, driving upstream and downstream collaboration. Meanwhile, internet giants such as Tencent, Alibaba, and ByteDance, through capital investment, technology enablement, and channel integration, have continuously strengthened the digital cultural consumption ecosystem, profoundly influencing content production standards, distribution models, and business strategies. Moreover, accelerated 5G deployment and cloud-network integration have enhanced real-time interactivity and cross-regional display capabilities of digital cultural products, providing technical support for high-quality online concerts, cloud art galleries, and virtual tourism[6]. Overall, under the joint impetus of policy support, market demand, and technological innovation, the digital cultural industry has entered a new phase characterized by large scale, strong branding, and intelligent development. Nevertheless, intensified content homogenization, increased difficulty in intellectual property protection and business model innovation, the digital divide, and ethical issues surrounding technology present fresh challenges—and underscore the vast potential for AI's deep empowerment of the industry.

3. Evolutionary Path of Artificial Intelligence Empowering the Digital Cultural Industry

3.1. Phase One: The Informatization Support Period

In the early 2000s through roughly 2010, the digital cultural industry entered what can be termed the Informatization Support Period. During this phase, stakeholders placed their primary emphasis on constructing robust network infrastructure—high-speed broadband, reliable data centers, and secure web hosting environments—to enable the large-scale digital

storage and transmission of cultural assets. Concurrently, institutions deployed a variety of digital tools such as Content Management Systems (CMS), digital asset repositories, and rudimentary online exhibition platforms. By investing in these basic yet essential components, museums, libraries, archives, and creative enterprises laid the groundwork for pervasive digital preservation. For example, many national libraries implemented open-source CMS platforms—customized Drupal or Joomla instances—to ingest and organize scanned manuscripts, photographs, and audio-visual recordings. These early efforts, though limited in interactivity, transformed static cultural artifacts into searchable digital collections accessible via the Internet. Within these nascent systems, the chief objective was twofold: first, to achieve “quantitative storage,” whereby artifacts were preserved in high-resolution digital formats; and second, to enable “automated retrieval,” whereby users could locate specific items through keyword searches and basic filters. Optical Character Recognition (OCR) engines—initially trained on general print fonts—were integrated to convert scanned text into searchable HTML or XML, while speech-to-text modules transcribed oral histories and audio tapes into text[7]. Simultaneously, institutions began to adopt standardized metadata frameworks such as Dublin Core and METS to ensure consistent description of their holdings. This metadata standardization proved essential, as it facilitated interoperability across disparate repositories and allowed for unified discovery interfaces. Although early metadata records were often incomplete or inconsistent in quality, they nonetheless enabled basic cross-collection search capabilities and laid a foundation for later, more sophisticated retrieval mechanisms. At this stage, artificial intelligence techniques were limited to rule-based engines and simple statistical algorithms. For example, batch-processing scripts automatically applied OCR text extraction, followed by keyword tagging routines that labeled each record according to a predefined taxonomy. Recommendation systems, where they existed, relied on collaborative filtering applied to user logs—matching users who viewed the same items—or on content-based filtering that compared simple textual features. While these rudimentary recommenders lacked deep semantic understanding, they nonetheless introduced a nascent personalization element into digital museum portals and streaming platforms. Visitors to early online exhibitions could receive suggestions for related artifacts based merely on shared keywords or prior navigation paths, offering a glimpse of how technology might one day guide exploration of vast cultural collections. From an industry perspective, the Informatization Support Period delivered several lasting benefits. First, the large-scale accumulation of digitized cultural assets created the data volume necessary for future AI training. By the end of this phase, many institutions had amassed millions of images, text documents, and audio segments—data that would later feed into deep learning models and knowledge graph construction. Second, the experience of deploying and maintaining automated pipelines fostered closer collaboration between curators, archivists, and technology teams. Joint working groups formed to resolve issues such as OCR accuracy, metadata schema alignment, and server scalability, establishing organizational procedures that would persist into later, more innovation-driven periods. Finally, the expansion of online dissemination channels—including simple gallery-style websites, institutional portals, and early social-media sharing—broadened public engagement with cultural heritage. Although user interactions remained largely passive, the increased visibility of digital offerings encouraged cultural organizations to plan more ambitious, AI-enabled applications in subsequent years. In summary, the Informatization Support Period was characterized by its focus on building the necessary infrastructure, data standards, and basic automated tools that transformed analog collections into digital repositories. These foundational investments in quantitative storage and automated retrieval not only improved content preservation and accessibility but also created the essential data and collaborative frameworks upon which the more sophisticated, AI-driven innovations of later phases would depend[8].

3.2. Phase Two: The Intelligent Integration Period

Beginning around 2010, with the maturation of deep learning, cloud computing, and big data technologies, AI rapidly gained prominence within the digital cultural industry. This Intelligent Integration Period is characterized by a shift from “AI-driven” to “scenario-integrated” ecosystems, moving beyond single-use algorithms toward closed-loop, multimodal, multi-touchpoint experiences. First, content production evolved from “human-assisted” to “AI-driven” creation. Technologies such as Natural Language Generation (NLG) and Generative Adversarial Networks (GANs) can now automatically produce creative outputs—text scripts, musical compositions, and digital illustrations[9]. For example, Transformer-based script-writing assistants generate coherent story segments from a user’s thematic outline, while GANs produce digital artworks that emulate the style of historical paintings. Second, personalization in distribution and consumption reached a deeper level. By monitoring user behavior in real time and fusing multiple data sources, platforms can accurately capture individual preferences, delivering one-to-one content matching and interaction in short-form video, live streaming, and cloud exhibition settings. In addition, knowledge graphs power contextual search and intelligent Q&A, allowing users to retrieve in-depth cultural background or artistic style information through natural dialogue—greatly enhancing both information discovery and cultural engagement. Third, immersive experiences rapidly emerged through AI’s integration with extended reality (AR/VR/MR). Intelligent computer-vision and behavior-recognition technologies enable users to interact “up close” with digital artifacts inside virtual museums. In digital performance events, AI-driven real-time motion capture and synthesis empower virtual idols and holographic concerts, breaking free of physical venue constraints and enabling cross-region, multi-device attendance. Finally, ecosystem collaboration and intelligent operations became prevailing trends. By deploying AI services across cloud and edge environments, every stage of the industry chain—from content planning and production to distribution and feedback—gradually achieved automated processes and intelligent scheduling. Concurrently, blockchain-based copyright protection and provenance systems have provided a trustworthy foundation for AI-powered applications, driving large-scale, platform-based, and intelligent integration across the digital cultural industry and supporting its sustainable development[10].

4. Case Studies of Typical Applications

4.1. Intelligent Content Creation and Recommendation

In the digital cultural industry, generative AI is reshaping traditional creative workflows. Leveraging large-scale pre-trained language models (e.g., the GPT series) and image-generation networks (e.g., GANs and diffusion models), creators can produce high-quality text scripts, poetry, shot lists for short videos, and digital illustrations from brief prompts. This human-machine collaboration drastically lowers the barrier to creation and significantly boosts productivity, enabling small studios and individual creators to generate professional-grade cultural works with limited resources. AI tools also assist in automated proofreading, style transfer, and multilingual translation, ensuring accuracy and cultural adaptation for international audiences. Intelligent recommendation systems use deep mining of user behavior data to fine-tune content distribution and personalization. Based on collaborative filtering, content analysis, and reinforcement learning algorithms, platforms model vast signals—clicks, watch time, social interactions—in real time, delivering customized content in formats such as short videos, live streams, and cloud exhibitions. Advanced multimodal recommendation methods further integrate text, image, audio-visual data, and user profiles into unified cross-media interest graphs, boosting both richness and precision. A continuous feedback loop enables the system to adapt to changing preferences and optimize push strategies, thereby increasing user engagement and platform activity. Notable examples include ByteDance’s

“relentless personalization,” whose core algorithms process billions of user actions per second to detect and distribute trending content instantly; the Shanghai Digital Museum, which uses knowledge graphs and recommendation models to suggest personalized exhibition routes, enhancing immersion and exploration; and digital music platforms that combine AI-driven playlist generation with sentiment analysis to deliver tracks matching listeners’ moods, substantially increasing listening time. These cases demonstrate that intelligent content creation and recommendation accelerate the scale and diversity of cultural production while enabling efficient value transmission and innovative monetization pathways through precise user matching.

4.2. Virtual Reality and Immersive Experiences

Virtual Reality (VR) and immersive experiences have become new conduits between audiences and cultural content. Using head-mounted displays, gesture recognition, and spatial tracking, users enter highly realistic virtual environments and interact directly with digitally reconstructed historical sites, artworks, or performance stages. This approach transcends physical constraints, allowing remote audiences to enjoy immersive exhibitions or performances. By integrating multiple sensory channels—visual, auditory, haptic, and even olfactory—VR significantly amplifies cultural transmission’s emotional impact and memorability. AI enhances these experiences in two key ways: scene generation and intelligent interaction. First, deep-learning-based 3D reconstruction and rendering automatically fuse 2D images, LiDAR point clouds, and historical records into high-precision virtual space models, accelerating scene creation and adding dynamic lighting and material realism. Second, intelligent dialogue and behavior-prediction models interpret users’ voice commands, gestures, and gaze, providing instantaneous content or guidance. For example, in a virtual museum, visitors can ask natural-language questions about an artifact’s provenance; the system, powered by a knowledge graph and semantic understanding, delivers background information or related exhibit suggestions. In immersive performances, the system adjusts lighting, sound, and narrative pacing in real time according to audience focus and emotional responses, crafting highly personalized viewing paths. Landmark projects include the Palace Museum’s “Digital Classroom,” which recreates Qing-era court scenes in VR for students’ virtual tours of the Forbidden City, and digital concert teams that combine AI motion capture with real-time rendering to enable interactive performances featuring virtual idols—viewers’ motions, expressions, and live chat can influence stage elements, boosting engagement and community identity. Some theme parks and cultural tourism sites integrate AI-powered VR with on-site exhibits through an “online reservation, on-site capture, online extension” model, forming a hybrid digital-physical cultural communication loop. Overall, VR and immersive experiences are evolving from simple visual simulations into highly intelligent, scenario-driven, and socialized offerings. As AI advances in rendering optimization, interactive intelligence, and multi-sensory feedback, future immersive cultural products will focus increasingly on designing personalized user journeys, achieving a profound fusion of technology and art, and fueling new growth engines for the digital cultural industry.

5. Future Trends and Challenges

5.1. Technological Evolution Trends

Deep intelligence enabled by multimodal fusion has become the core driving force behind next-generation digital cultural products. Iterative upgrades of large-scale pre-trained models are evolving beyond single-modality text or image generation toward joint training on text, images, audio, and video. Through multimodal representation learning, systems can capture richer semantic relationships from massive cross-media data, not only enhancing content diversity but also providing a unified technical foundation for cross-scenario immersive experiences. As

model sizes continue to grow and algorithms are further optimized, content-creation and recommendation systems will become better at understanding cultural contexts, realizing true “intelligent co-creation.” Breakthroughs in real-time rendering and interaction performance will deliver even stronger immersion in virtual environments. By leveraging edge computing in concert with 5G/6G networks, complex 3D rendering and AI inference can occur on local devices or at edge nodes near users—dramatically reducing latency and offloading the central cloud. Combined with point-cloud reconstruction, light-field displays, and haptic feedback technologies, user motions, gaze tracking, and environmental responses in virtual museums and digital performances will become seamlessly integrated, yielding a qualitatively deeper sense of presence. A deeper integration of knowledge graphs with explainable AI will open new possibilities for intelligent cultural content retrieval and personalized recommendation. By structuring domain knowledge, systems can support semantic-level cultural Q&A and recommendation path planning, while presenting visualized knowledge pathways alongside suggested content to build user trust in system decisions. Moreover, explainability techniques will play a critical role in copyright protection, content moderation, and ethical compliance—helping cultural institutions innovate responsibly. At the foundational infrastructure level, decentralized technologies and secure, trustworthy computing are becoming essential enablers for industry deployment. Blockchain-based digital copyright management platforms, coupled with AI-generated-content provenance and verification mechanisms, will ensure artwork origins are traceable and rights allocations verifiable. Federated learning and privacy-preserving computation will enable collaborative training across multiple organizations and heterogeneous data sources without exposing sensitive information. As hardware compute continues to shift toward heterogeneous accelerators and neural-network-specific chips, future digital cultural products will combine high performance with scalability—providing a robust foundation for large-scale, intelligent deployments.

5.2. Ecosystem and Policy Challenges

Today’s digital cultural industry is evolving rapidly toward deep intelligent integration, yet it faces challenges in ecosystem collaboration and regulatory governance. On the ecosystem side, the tension between major platforms and small-to-medium creators is becoming ever more pronounced. Large internet companies leverage capital and technology advantages to build a complete closed-loop—from content production to distribution to monetization—while smaller teams and individual creators often lack fair access to traffic channels and algorithmic recommendation mechanisms. Data silos between platforms remain a major barrier: there is no unified standard for cross-platform, multi-source data sharing, hindering multi-institution innovation and collaborative ecosystems. Furthermore, the cultural industry’s long value chain—upstream content production, midstream technical services, and downstream distribution channels—often operates in silos, lacking effective mechanisms for equitable profit sharing and risk sharing, which can lead to imbalanced value returns and innovation discontinuities. On the policy and regulatory side, outdated laws and regional disparities constrain AI-empowered digital cultural applications. Existing copyright regimes lack provisions for AI-generated content, making it difficult to define rights for original versus derivative works. Although data-compliance and privacy protection regulations have gradually improved, cross-border data flows and large-scale user-behavior analysis still incur high compliance costs and complex approval processes. Meanwhile, oversight of AI model transparency and algorithmic bias remains in its infancy: there are no unified evaluation metrics or review frameworks, leaving intelligent recommendation and virtual-idol applications open to safety and ethical concerns. Policymakers must strike a balance between encouraging technological innovation and safeguarding the public interest, establishing a more inclusive regulatory framework and standardized best practices to promote a healthy, sustainable digital cultural ecosystem.

6. Policy and Practical Recommendations

6.1. Policy Recommendations

To accelerate deep integration of AI and the digital cultural industry, governments should craft a regulatory environment that balances innovation with protection. First, copyright law and database protection statutes must be refined to clarify ownership of AI-generated works, define fair-use boundaries, and establish licensing mechanisms for derivative content—thereby fostering innovation while safeguarding original creators' rights. Second, data-sharing and privacy-protection guidelines should encourage cultural institutions and platforms to share annotated, structured cultural resources in full compliance with regulations, providing lawful, standardized data support for AI model training and services. Additionally, governments can offer targeted funding, tax incentives, and hardware-software subsidies to lower the R&D and application costs for small and medium-sized cultural enterprises and creators, promoting collaboration across the industry value chain.

6.2. Practical Recommendations

Cultural organizations and technology teams should build cross-disciplinary innovation mechanisms. Content providers must collaborate with AI researchers to define data standards and annotation processes, ensuring training data quality and diversity to enrich cultural depth and aesthetic value. During product development, algorithmic transparency and explainability should be design principles: leveraging knowledge graphs, visualized decision pathways, and user-feedback loops will help audiences understand the logic behind recommendations and generated content, strengthening trust and engagement. Organizations should fully exploit cloud-edge-device collaborative architectures—conducting large-scale model training and distribution in the cloud while performing real-time inference and rendering at the edge or on devices—to maintain smooth, stable immersive experiences. Finally, talent development and organizational change are essential: fostering multimodal collaboration among cultural managers, creative professionals, and AI engineers via joint laboratories, open sandbox environments, and industry forums will continuously iterate application scenarios and technical solutions—ensuring the digital cultural industry's sustainable innovation and high-quality growth.

7. Conclusion

Drawing on a two-phase evolutionary perspective of “Informatization Support → Intelligent Integration,” this study systematically maps AI's empowerment of the digital cultural industry, analyzes representative applications, and examines future trends alongside ecosystem and policy challenges. Findings show that the Informatization Support Period established the large-scale data accumulation and metadata governance necessary for deep-learning and knowledge-graph development; the Intelligent Integration Period, in turn, has driven automated content creation, optimized personalized recommendation, and accelerated immersive experience deployment—yielding transformative gains in production efficiency, user engagement, and value realization. Emerging trends in multimodal fusion, edge collaboration, and explainable AI will further elevate cultural-scene intelligence. Yet challenges remain: platform monopolies versus small-creator equity, data-sharing barriers, unclear copyright for AI-generated content, and gaps in algorithmic governance. Overall, AI's evolution in the digital cultural industry represents not only technology-driven innovation in production and distribution but also a reconstruction of the industry ecosystem and value chain. Going forward, governments should enact comprehensive regulations and incentives; cultural enterprises and tech partners must deepen cross-sector collaboration, enhance algorithmic transparency, and build user trust; cloud-edge-device architectures should guarantee application performance; and continuous

investment in talent and organizational transformation is vital. Only by aligning technological innovation with sound governance can the digital cultural industry achieve high-quality, sustainable development and foster a richer, more diverse cultural ecosystem.

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