Preliminary Exploration of the Application of Broadcasting Technology in the Digital Dissemination of Tangible Cultural Heritage (Postprint)

Authors: Zhu Xiaoyu, Wang Yongde, Weng Junhua, Ning Yongqiang

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Abstract

Objective: The application of broadcasting technology in the digital dissemination of cultural heritage sites and artifacts is gradually becoming a vital instrument for cultural heritage preservation and transmission. **Method:** Through the comprehensive utilization of established data resources in the cultural domain, coupled with mining, analysis, and processing, a collection of high-quality, thematically diverse, and exquisitely crafted digital cultural tourism resources is generated. By employing new technologies such as AI large models, intelligent voice interaction, and digital scene interaction, sustainable, scalable, secure, and reliable cable television terminal digital culture AI interactive applications are produced. **Results/Conclusion:** This paper, using digital culture interactive applications as a case study, systematically delineates the key technologies, television-end application presentation, advantages, and existing challenges of broadcasting technology in the digitization of material cultural heritage.

Full Text

A Preliminary Study on the Application of Radio and Television Technology in the Digital Dissemination of Material Cultural Heritage

Zhu Xiaoyu[1], Wang Yongde[1], Weng Junhua[1], Ning Yongqiang[2]
[1]. China Cable Television Network Co., Ltd. Hainan Branch, Haikou, Hainan 570100;
[2]. Weijing Tianxia (Beijing) Technology Co., Ltd., Beijing 100089

Abstract

[**Purpose**] The application of radio and television technology in the digital dissemination of cultural heritage sites and artifacts is becoming an important tool for cultural heritage protection and inheritance. [**Method**] By systematically utilizing established data resources in the cultural sector and mining, analyzing, and processing them, we produce a batch of high-quality, diverse, and well-crafted digital cultural tourism resources. Through the application of new technologies such as AI large models, intelligent voice interaction, and digital scene interaction, we develop sustainable, scalable, and secure digital cultural AI interactive applications for cable television terminals. [**Results/Conclusion**] This paper systematically describes the key technologies, television-side application presentation, advantages, and existing challenges of radio and television technology in the digitalization of material cultural heritage, using digital cultural interactive applications as case studies.

Keywords: Radio and television technology; Cultural heritage dissemination; Application of AI large models; Intelligent voice interaction; Digital scene interaction
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Material cultural heritage constitutes an essential component of China' s outstanding traditional culture, bearing the historical memory and cultural genes of the Chinese nation. With the rapid development of digital technology, radio and television technology is playing an increasingly important role in the digital dissemination of material cultural heritage. In recent years, China has attached great importance to the protection and inheritance of material cultural heritage, issuing a series of policy documents that emphasize strengthening the dissemination of material cultural heritage and encouraging various new media platforms to undertake related communication work. Guided by these policies, radio and television, as traditional media, have actively employed digital means to record, disseminate, and promote material cultural heritage [1]. This study leverages the robust network infrastructure of the national broadcasting backbone network and the cable television network interconnection platform, combined with advanced digital technologies such as large models, artificial intelligence, and 3D visualization, to aggregate and store digital resources related to Chinese culture and tourism—including images, text, panoramas, and 3D models—while enabling online and offline interaction. Based on television-side display, the digital cultural interactive application allows users to access and watch digital cultural content anytime, participate in interactive experiences, receive person-

alized recommendations from cultural agents regarding cultural content, engage in intelligent Q&A with these agents, and conveniently access and gain in-depth understanding of cultural and tourism resources nationwide.

1. Key Technologies of Radio and Television Technology in Digital Cultural Interactive Applications

Large models, intelligent voice, and 3D visualization are transforming the world profoundly. Large models, as a milestone in AI development, refer to deep learning models with parameter scales exceeding hundreds of millions or even hundreds of billions, such as GPT and BERT. These models are characterized by high capacity to capture complex patterns and distributions, versatility to support multiple tasks and multimodal learning, and scalability to complete specific tasks through fine-tuning with few samples or unsupervised learning.

1.1 Large Model Infrastructure

The large model infrastructure serves as the foundational architecture and technical system supporting the operation, development, and application of large models. It provides comprehensive support for computing, storage, data processing, and algorithm optimization, encompassing capabilities in language understanding, text generation, knowledge Q&A, multimodal interaction, logical reasoning, mathematical ability, and code generation. The infrastructure includes intelligent computing servers and full lifecycle tools supporting large models from training and integration to application. These tools cover core functions such as model training, model fine-tuning, dataset management, model management, API management, and online testing to meet the requirements of large model development, deployment, and application across different scenarios.

In the broadcasting and television field, the large model infrastructure' s powerful data processing capabilities enable it to handle the massive volumes of data transmitted through cable television—including video and audio streams—by efficiently parsing and processing these complex and diverse streams simultaneously. It can accurately identify every frame in videos and analyze every note in audio, ensuring no critical information is lost during high-speed data transmission, thereby laying a solid foundation for subsequent content analysis and processing. User behavior data represents another crucial data source in the cable television domain. By gaining deep insights into user behavior, broadcasting operators can better understand user preferences, viewing habits, and consumption patterns. The large model infrastructure can collect and integrate user behavior data from various channels, including operation records on television terminals such as channel switching, program searching, pausing, and fast-forwarding, as well as interactive behaviors on related applications like program reservations, comments, sharing, and favorites. It aggregates and cleans these scattered data, transforming them into structured information for in-depth analysis. For instance, by analyzing the types of programs users fre-

quently watch, viewing time distributions, and device preferences, operators can precisely grasp user needs and provide more personalized services.

The large model infrastructure also features efficient model inference speed. In the broadcasting and television field, users have extremely high requirements for service response speed, expecting instant feedback whether switching channels, searching for programs, or conducting voice interactions. With its powerful inference capabilities, the large model infrastructure can quickly respond to various user requests. When a user presses a button on the remote control or issues a command through a voice assistant, the infrastructure can parse and process the request within milliseconds. It rapidly retrieves information matching user needs from the vast program database or generates personalized program recommendation lists based on user history and preferences. When searching for programs, the infrastructure can semantically understand and analyze user-input keywords within milliseconds, accurately match them in the massive program library, and quickly return relevant program information. This rapid response not only enhances user viewing experience but also improves satisfaction and loyalty. For real-time interactive scenarios such as live program interactions, the large model infrastructure' s fast inference speed is particularly critical. It can process user-sent bullet comments and reviews in real time and quickly display them in the live broadcast, enabling instant interaction between audiences and hosts and creating a more active live atmosphere.

1.2 Intelligent Voice Technology

Intelligent voice technology is a highly comprehensive discipline that integrates knowledge from computer science, linguistics, psychology, and artificial intelligence. Its core objective is to endow computers with the ability to understand and process human speech, thereby achieving natural voice interaction between humans and machines. Through intelligent voice technology, computers are no longer limited to receiving and executing simple commands but can communicate with humans more fluently and naturally through speech recognition, speech synthesis, and natural language processing.

Combining AI voice capabilities, large model capabilities, and virtual digital human capabilities, we develop a visual voice assistant driven by large models around home business development needs. Integrated with voice control, it enables television entry points such as voice remotes and achieves seamless voice control integration with large screens. Based on the large model' s understanding of broadcast media assets, it enables natural language-based TV program searching. By integrating broadcast media assets and operational data, it adds dimensions to customer operations. The system provides functions including voice interaction, sensitive word filtering, voice usage guidance, voice service authentication, live broadcast management, replay management, multi-domain content search, application operations, voice-enabled lifestyle mini-applications, and operational support services.

Smart broadcasting voice offers new scenario services such as home encyclopedia consultation, story co-creation, video assistant, and emotional companionship. Users can directly complete channel switching, program searching, and volume adjustment through voice commands without complex menu navigation, greatly simplifying operation processes and enhancing user experience. The intelligent voice interaction system based on large language models can more deeply understand user needs and create more convenient and pleasant experiences through intelligent, personalized, and contextual interaction design. The smart broadcasting voice assistant also features efficient speech recognition capabilities, provides voice usage guidance, accurately identifies user voice commands, and responds quickly. It supports natural language interaction, filters sensitive words, and enables users to communicate with televisions using everyday language, improving user experience. Smart broadcasting voice can recommend movies, TV series, and variety shows based on users' viewing history and preferences. It also supports multi-domain voice search—users can quickly find desired programs or films by simply speaking keywords—and provides lifestyle services such as weather checks, holiday inquiries, stock checks, and schedule reminders. Additionally, smart broadcasting voice can provide various encyclopedic information and application services covering life 常识, health and wellness, home maintenance, cooking skills, travel suggestions, and other fields, offering personalized and 贴身 information query services. For complex or difficult concepts, the system provides detailed explanations and examples to help users better understand.

1.3 3D Visualization

3D visualization is a technology that converts 3D data into intuitive visual images. Based on computer graphics principles [3], it creates 3D geometric models of objects through 3D modeling software or measurement data, defining their shape, size, position, and posture. According to lighting models and material properties, it calculates the color and brightness of each pixel on the model surface to generate realistic visual effects, transforming abstract 3D data into graphics and images that people can intuitively understand. Users interact with 3D scenes through devices such as mice, keyboards, and touchscreens—rotating, translating, and scaling objects—to view 3D models of cultural artifacts from different angles. It can also display 360° panoramas of cultural and tourism-related venues such as museums and scenic spots.

2. Core Scenarios and Cases of Digital Cultural Interactive Applications

Leveraging advanced technologies such as big data, intelligent voice, and 3D visualization, we optimize and upgrade the existing national cultural big data platform. By constructing a high-performance data processing and analysis infrastructure and an intelligent application service system, we achieve rapid transmission, efficient processing, and intelligent application of cultural data,

providing comprehensive technical support for the digital transformation of the cultural industry. Digital cultural interactive applications conduct demonstration projects in provincial cable television networks, verifying platform feasibility and practicality through practice and laying a solid foundation for future digital applications of material cultural heritage.

The digital cultural interactive application collects diverse cultural data reflecting Chinese culture and tourism, covering 3D models, real scenes, images, audio, video, text, and other data types. Through multi-source data visualization fusion and AI and large model technologies, it reproduces digital cultural content on television terminals, achieving dissemination of digital Chinese cultural content. Based on television-side display, users can access and watch digital cultural applications anytime, participate in interactions, experience personalized recommendations from cultural agents, engage in intelligent Q&A, and conveniently access and deeply understand cultural and tourism resources nationwide.

The digital cultural interactive application system adopts a layered architecture. Following the workflow of content production, operation management, and application, we develop technical modules from bottom to top. The system employs container-based development and deployment, supporting elastic scaling and high availability. System functions adopt a microservices architecture, with each functional module implemented through standard interfaces and high cohesion to ensure unified standard external services while meeting distributed deployment and fine-grained functional requirements. The implementation strictly follows standard architectural specifications to ensure high compatibility with related system interfaces. The architecture consists of five layers from bottom to top: infrastructure, resource, support, application, and presentation layers [4]. The system architecture is shown in Figure 1 [Figure 1: see original paper].

2.1 System Architecture Design

2.1.1 Infrastructure Layer This layer serves as the foundational environment for system construction. The entire system is built on the China Cable Cloud basic platform, providing essential network infrastructure and transmission channels required for data communication, display, and application of various system applications.

2.1.2 Content Resource Layer The resource layer supports the core data requirements of various system applications, accelerating their implementation, standardization, and interconnectivity.

2.1.3 Business Support Layer The support layer provides business support capabilities for application layer functions, including access statistics support, resource management support, content production support, operation management support, and other basic support systems, as well as a highly extensible standardized data connection middleware layer.

2.1.4 Business Application Layer The application layer implements business applications such as digital interactive content display services and cultural agent interactions.

2.1.5 Presentation Layer This layer implements system application display capabilities, providing human-computer interaction functions between users and the system. The system supports television-side display to meet the general application needs of cable television user groups.

2.2 Digital Cultural Content Operations

Digital cultural content operations include content planning, creation, publishing, data analysis, and user interaction. Through diverse content and immersive interactive experiences, we enhance the 趣味性 of television-side content and increase user engagement and stickiness.

2.2.1 Cultural Content Planning Combining different seasons, special festivals, cultural tourism hotspots, and representative cultural and tourism content, we plan 25 digital cultural content topics annually at a frequency of 2 issues per month plus 1 special Spring Festival issue. Each topic averages 20-30 minutes of browsing time and contains 6-8 content items. These topics not only enhance the 趣味性 of television-side content but also drive active user participation and stickiness.

2.2.2 Cultural Content Topics Cultural content topics include cultural tourism guides, digital cities, digital exhibitions, digital artifacts, traditional villages, intangible cultural heritage, special features, and cultural audio/video. We select the 25 most representative items across these categories to form the annual digital cultural content operation system.

(1) Cultural Tourism Guides
These provide detailed travel guides, virtual cloud tours, route introductions, and scenic spot descriptions, allowing users to appreciate beautiful scenery while obtaining practical travel information and services that enhance their experience and practicality.

(2) Digital Cities
Through aerial photography of city landmarks, cultural tourism feature displays, urban architecture, cultural districts, and natural landscapes, users can cloud-tour major Chinese cities without leaving home.

(3) Digital Exhibitions
Through virtual exhibition halls and online exhibitions, users can cloud-visit 精品 exhibitions in major national museums, art galleries, and art museums, enjoying the charm of cultural and artistic treasures nationwide from home.

(4) Digital Artifacts
Including cultural relics, historical sites, and historical buildings, this category

presents complete appearances and details of artifacts through 3D scanning and high-definition imaging, allowing users to observe every detail and understand production techniques and historical backgrounds [5].

(5) Traditional Villages
This category immersively displays the natural scenery, architectural styles, and cultural characteristics of traditional villages through aerial photography, protected buildings, and cultural heritage. Users can experience the tranquility and beauty of traditional villages while learning about local folk activities and handicraft production processes. This section showcases China' s rich and colorful rural culture, evoking users' yearning for rural life and identification with traditional culture.

(6) Intangible Cultural Heritage
This introduces the historical origins, inheritance status, and technical characteristics of intangible cultural heritage projects to raise user awareness and protection consciousness. Content includes oral traditions, traditional performing arts, folk activities, festival rituals, and traditional handicrafts. Each project features detailed video introductions and live demonstrations, allowing users to experience intangible cultural heritage techniques up close.

(7) Special Features
This showcases special cultural topics such as Great Wall culture, red culture, and stage art culture. Each topic deeply explores cultural connotations through text, video, and interactive displays, comprehensively presenting historical backgrounds and current status. Users can gain in-depth understanding of these topics' unique charm and important value through television, enhancing cultural confidence and national pride.

(8) Cultural Audio/Video
This aggregates rich cultural films, music, and courses. Users can appreciate classic cultural film and television works, listen to beautiful traditional music, and even learn cultural knowledge through television screens.

2.2.3 Content Display Forms Cultural content employs diverse presentation forms on the digital cultural content operation platform, including cultural images, text, audio, video, 360° panoramic displays, and 3D data presentations. To ensure optimal user experience, the platform employs high-performance media players and advanced 3D rendering engines to ensure smooth display of images, audio, video, and 3D models.

(1) Image Display
High-definition images are displayed with zoom and swipe support, allowing users to appreciate the delicate details of artifacts or scenic spots up close while providing an interactive learning and exploration platform.

(2) Text and Image Information
Detailed text and image information displays names, ages, historical back-

grounds, and other key information, enabling users to comprehensively understand the connotation and value of each cultural heritage item.

(3) Audio Playback
The platform provides vivid and rich exhibition experiences through audio playback. Users can listen to expert explanations, background music, or sound effects to gain deeper understanding of the stories and history behind exhibits or scenic spots.

(4) Video Playback
Video playback is an important method for displaying topic-related content. Through documentaries and short videos, users can comprehensively understand culture-related content both visually and aurally.

(5) 360° Panoramic Display
This function provides users with an immersive visiting experience. Users can explore the environment and details of artifacts or scenic spots as if they were visiting in person.

(6) 3D Model Display
Through high-performance 3D rendering engines, the platform displays 3D models of related artifacts or scenic spots. Users can freely rotate and scale models to explore spatial structures and artistic designs in depth.

(7) Comprehensive Display
This organically combines images, audio, video, 360° panoramas, and 3D models to display cultural topics comprehensively, providing users with richer and more comprehensive cultural experiences.

2.2.4 Content Creation Content creation is the core of content operations, attracting users, delivering value, and achieving goals through high-quality content. The creation process mainly includes material collection, visual design, and content production. Material collection involves gathering and organizing content-related materials through multiple channels. Visual design enhances visual effects and user experience through various design tools and technologies. Content production involves creating attractive, information-rich content that effectively conveys information or emotions through text, images, audio, video, and other forms.

(1) Material Collection
Digital cultural materials come from diverse sources, including historical documents, academic papers, news reports, photographic works, audio archives, video clips, and panoramic 3D resource libraries. To ensure material diversity and authenticity, we collaborate with professional organizations such as museums, libraries, archives, and academic institutions to obtain authoritative materials. Through detailed screening and organization, materials are classified and archived to provide a solid foundation for subsequent creation. High-quality, diverse materials not only enhance content professionalism and credibility but

also provide rich inspiration and ideas for subsequent creation.

(2) Visual Design
We employ various design tools and technologies to add visual effects to cultural content presentation, enhancing user experience and content appeal. The design process combines characteristics of different content themes to create artistic and attractive color schemes, layouts, and graphic designs. To ensure high-quality design works, we reference design trends and user preferences, presenting the best results through multiple revisions and improvements. Visual design focuses not only on aesthetics but also on information communication, enabling users to intuitively understand core cultural content information. Through clever design, we enhance overall content appeal and user experience, strengthening user interest and stickiness.

(3) Content Production
Content production combines collected materials, thoughtful creative concepts, and clear target audience needs to create attractive, information-rich content products that effectively convey information or emotions through text, images, audio, video, and other forms. For content topics with insufficient existing resources, we conduct content creation such as high-definition photography, panoramic data capture, and 3D data modeling to ensure complete topic presentation.

2.3 Digital Cultural Interactive Display

The digital cultural interactive application aggregates and integrates digital resources related to culture and tourism, displaying them diversely according to different content themes. It also provides cultural agents that use artificial intelligence and speech recognition technology, integrated with large model capabilities, to more intelligently understand and process user queries, providing more personalized answers based on user intent and context. This enables users to more conveniently access and deeply understand cultural and tourism resources nationwide. The digital cultural interactive application displays through television terminals, allowing users to understand rich and wonderful digital cultural content without leaving home, engage in immersive interactive experiences, explore cultural treasures through AI interaction, and experience the unique charm of the intersection of technology and culture.

2.3.1 Cultural Topic Display The cultural topic display section mainly includes homepage comprehensive display, topic display, past review, and topic classification.

Homepage Comprehensive Display: The digital cultural interactive application homepage displays intelligent agent interaction modules, topic categories, featured homepage content, past reviews, content search bars, and other flexible display modules to serve users.

Topic Display: Regularly launching rich and colorful topic content aims to

bring users diverse digital cultural experiences. After each carefully planned topic goes live, users can explore the latest cultural content with a simple click, covering cultural tourism guides, digital cities, digital exhibitions, digital artifacts, traditional villages, intangible cultural heritage, special features, and cultural audio/video.

Topic Classification: On the application homepage and in each topic category, users can open topic display content by clicking topic cards, which are displayed in waterfall flow format in each category. Topic display provides multiple content types including images, text, audio, video, 360° panoramas, and 3D data, using high-performance media players and 3D rendering engines to ensure smooth display of images, audio, video, and 3D models (Figure 2 [Figure 2: see original paper]).

Past Review: By clicking the past review module, users can view previously launched topic content. The past review page contains two modules: user viewing history (displaying recently watched topics in reverse chronological order) and past topics (displaying recently updated topics in reverse chronological order) (Figure 3 [Figure 3: see original paper]).

2.3.2 Application Interaction The digital cultural interactive application provides two main interaction methods: artificial intelligence (AI) voice interaction and remote control interaction.

(1) Artificial Intelligence (AI) Voice Interaction
Integrated with AI voice dialogue capabilities, users can conduct conversational interactions with cultural agents provided in the application. Cultural agents can provide topic recommendations, topic searches, detailed cultural content explanations, and knowledge Q&A. Users can also conduct content searches, topic switching, or media playback through voice commands, greatly simplifying operation processes and improving efficiency.

- **Dialogue Interaction:** Supports users in clicking on cultural agents to conduct conversational interactions, with dialogue content displayed as speech-to-text in the conversation window.
- **Topic Recommendation:** Cultural agents provide personalized recommendations for cultural topic content based on user browsing history and other data.
- **Topic Search:** Users can command cultural agents to search for topic content through voice instructions, with search results presented as cards in the dialogue box.
- **Knowledge Q&A:** Users can ask questions to cultural agents through voice commands and engage in knowledge Q&A.
- **Application Operations:** Users can command cultural agents to perform application operations including topic switching, topic video content playback, panoramic content playback, and volume adjustment (Figure 4 [Figure 4: see original paper]).

(2) Remote Control Interaction
- **Basic Operations:** Supports basic operations through remote control buttons, including opening applications, selecting topic content, viewing topic content through confirmation buttons, and adjusting background music volume through volume up/down buttons. - **Application Operations:** Supports viewing special display content through remote control buttons, including panoramic drag viewing, 3D model rotation viewing, and zoom in/out viewing.

3. Application Advantages and Existing Challenges

Radio and television technology offers multiple advantages in the digitalization of material cultural heritage:

3.1 Advantages

3.1.1 Collection and Recording High-definition camera technology in radio and television can capture the details of material cultural heritage, whether the carvings on ancient buildings, the color textures of murals, or the subtle features of artifacts, all of which can be clearly recorded to provide high-quality image materials for subsequent digital processing and display. Beyond visual information, radio and television technology can also collect audio information, such as the sound of ancient buildings in the wind, traditional music related to artifacts, or story narrations, enriching the content dimensions of material cultural heritage digitalization and enabling more comprehensive perception of cultural heritage.

3.1.2 Mass Data Storage The construction of large model infrastructure, utilizing cloud computing, big data analytics, and large model technologies, enables centralized storage, management, and analysis of cultural heritage and artwork data, improving data availability and value. It achieves intelligent analysis and application of cultural data, supports data sharing and collaboration, promotes data aggregation and cross-application across various fields, and provides strong support for cultural innovation and diversified services.

3.1.3 Secure and Wide-Area Transmission The national broadcasting backbone network, as the national cultural dedicated network, ensures the security of national cultural data and prevents cultural genetic data from being stolen or leaked. After years of construction, the broadcasting network has covered urban and rural areas, including remote regions, enabling the national cultural dedicated network to disseminate cultural resources to broader areas and allowing more people to enjoy the achievements of cultural digitalization. Additionally, the national broadcasting backbone network features high bandwidth and low latency transmission capabilities, ensuring high-definition and smooth transmission of cultural digitalization content and providing users with high-quality audio-visual experiences.

3.2 Challenges

3.2.1 Technical Level Lack of Unified Technical Standards: Currently, the application of radio and television technology in material cultural heritage digitalization lacks unified technical standards and specifications. Different regions and institutions may adopt different technical methods and formats in digitalization work, resulting in poor data compatibility and interoperability, which hinders the integration and sharing of cultural heritage digital resources.

3.2.2 Protection and Inheritance Level (1) Risk of Information Distortion: During digital collection, processing, and dissemination, technical limitations or human factors may cause distortion of material cultural heritage information. For example, inaccurate color reproduction in images or loss of artifact details can affect people' s understanding and recognition of the true appearance of cultural heritage.

(2) Insufficient Cultural Connotation Mining: The application of radio and television technology in material cultural heritage digitalization often focuses more on formal display than in-depth excavation and interpretation of cultural connotations. Simply presenting cultural heritage digitally without deeply explaining its historical, cultural, and artistic values makes it difficult for audiences to truly understand and appreciate the charm of cultural heritage.

3.2.3 Personnel and Funding Level (1) Shortage of Professional Talents: Material cultural heritage digitalization requires interdisciplinary talents who understand both radio and television technology and cultural heritage protection knowledge. However, such professionals are currently relatively scarce, limiting the in-depth application and development of radio and television technology in the cultural heritage digitalization field.

(2) Limited Funding: Material cultural heritage digitalization requires substantial funding for equipment procurement, technology development, personnel training, and data maintenance. For some economically underdeveloped regions or small cultural institutions, funding shortages are a significant factor restricting digitalization construction.

With rapid technological development, using digital means to innovate presentation forms and enrich digital content, and building new cultural business forms characterized by cultural experience and application, will gradually transform cable television from traditional broadcast program transmission to deep expansion and connection across the entire propaganda and cultural field, thereby promoting innovative development of the cultural tourism industry. Meanwhile, applications based on large model infrastructure will become an inevitable trend for the future development of broadcasting and television [6]. Under the support of large model infrastructure, various applications interconnect in the broadcasting backbone network with the highest security protection level, making the development of broadcasting and television digital cultural interactive applications

more convenient and enriching and comprehensively upgrading broadcasting networks through the construction of various digital cultural interactive applications, enabling them to play an important role in implementing the national cultural digitalization strategy.

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About the Authors:
Zhu Xiaoyu (1982–), female, from Haikou, Hainan, bachelor' s degree, intermediate engineer, deputy department manager, research interests include digital broadcasting television terminal evolution, user interaction experience, and ultra-high-definition transmission technology.
Wang Yongde (1972–), male, from Chengmai, Hainan, bachelor' s degree, senior engineer, deputy general manager, research interests include new broadcasting networks, digital television technology, streaming media, ultra-high-definition, artificial intelligence, and network security.
Weng Junhua (1979–), male, from Lingao, Hainan, bachelor' s degree, senior engineer, department manager, research interests include digital broadcasting television business in end-to-end ultra-high-definition transmission bearing network technology for new broadcasting networks.
Ning Yongqiang (1978–), male, from Luoyang, Henan, master' s degree, senior engineer, chairman, research interests include digital protection, inheritance, and utilization of cultural heritage, terminal applications of cultural tourism large models, and cultural tourism intelligent agent technology.

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Note: Figure translations are in progress. See original paper for figures.