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Exploration of the application of virtual digital human technology in rural cultural and tourism—Digital transformation pathways from the perspective of scene theory

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Abstract. This paper explores the application path of virtual digital human technology in rural cultural and tourism from the perspective of scene theory. Through in-depth interviews with 17 practitioners in Zhejiang Province and multi-case analysis, the paper reveals the three-dimensional dilemmas of rural cultural and tourism in terms of operational mechanisms, infrastructure, and industrial ecology. A "technology-space-relationship" collaborative model is proposed, and the paper demonstrates how virtual digital humans, through immersive interaction, virtual scene reconstruction, and cultural IP value-added empowerment mechanisms, can provide both theoretical and practical paradigms for the digitalization of rural cultural and tourism.

Keywords: virtual digital human, rural cultural and tourism, scene theory, digital transformation, immersive experience

1. Introduction

As a core vehicle of the rural revitalization strategy, rural cultural and tourism is facing a threefold dilemma: experience homogenization, insufficient cultural dissemination effectiveness, and a fragile industrial ecology. Although technologies like VR/AR and digital twins have gradually been applied in cultural and tourism scenarios, traditional digital paths mostly focus on improving information display efficiency and have not effectively solved deeper contradictions such as superficial cultural narratives and low tourist engagement. Especially in rural areas, the geographical marginality leads to fluctuations in tourist numbers, infrastructure lag causes supply-demand mismatch, and the absence of community participation results in cultural identity fragmentation, further restricting sustainable development. In this context, the breakthrough application of virtual digital human technology offers a new approach to addressing these challenges: through intelligent interaction and humanized narratives, it can reconstruct "physical-virtual" hybrid scenarios, transforming cultural communication from one-way output to an immersive co-creation model.

Based on Clark's scene theory, this paper analyzes how virtual digital human technology drives the digital transformation of rural cultural and tourism, focusing on space reshaping, behavioral interaction, and cultural narratives. The study selects 11 digital demonstration projects from six cities in Zhejiang Province as cases, using a combination of semi-structured interviews (N=17) and multi-case grounded analysis methods. The paper addresses the following issues: The core bottlenecks and mechanisms of rural cultural and tourism digital transformation; How virtual digital human technology can achieve cultural value enhancement through scene reconstruction; The collaborative path of community participation and cultural heritage under technological empowerment. By constructing a "technology-space-relationship" three-dimensional collaborative model, this paper aims to provide a theoretical framework for the digital practice of rural cultural and tourism and open up new perspectives for research on technology-driven cultural dynamic inheritance.

2. Literature review

2.1. Mechanisms of digital technology empowering the integration of rural culture and tourism

The integration of rural culture and tourism has become an increasingly popular tourism model that attracts growing attention worldwide. In China, with the implementation of the rural revitalization strategy, rural culture and tourism have not only become

a new engine for local economic development but also an important way to preserve cultural heritage and promote ecological protection [1]. Rural areas possess abundant intrinsic resources, and the vast natural, material, and cultural heritage remains to be developed and promoted. In the context of global industrial transformation and integration, the fusion and innovation of rural culture and tourism with other industries is inevitable [2]. The expected outcomes of rural culture and tourism development, both domestically and internationally, can be categorized into economic and non-economic factors. From an economic perspective, expanding the development of rural culture and tourism can increase local incomes, create jobs, effectively promote the optimization and upgrading of rural industrial structures, and improve the quality of life for farmers [3]. From a non-economic perspective, the focus of rural cultural construction has traditionally been achieved through the establishment of public cultural service venues [4]. At the same time, the rapid development of urban culture, driven by economic growth, has impacted the identity of indigenous rural culture [5]. Therefore, through necessary measures to promote local tourism development based on local culture, the recognition of local culture can be enhanced both within and beyond the community [6]. It is worth noting that the application of digital technologies to comprehensively optimize the supply side of traditional cultural tourism and integrate big data to create an integrated management system is an inevitable trend in the development of the times [7]. Furthermore, emerging virtual human technologies provide new opportunities for rural culture and tourism. Through virtual tour guides, interactive experiences, and other methods, they can enhance visitors' sense of participation and experience, thereby improving the brand image of rural culture and tourism.

2.2. Virtual digital humans: technological spectrum and reconstruction of cultural and tourism application scenarios

Virtual digital humans are a byproduct of social digital transformation [8]. They exist in the virtual world and are created using digital technologies to closely resemble human figures. Researchers define virtual digital humans serving rural culture and tourism as: digital entities that exist in the virtual world and are based on technologies such as graphic rendering, motion capture, deep learning, and speech synthesis [9]. These digital entities have multiple human characteristics, such as detailed and similar appearances, voices, behaviors, and emotional expressions, and they can provide users with certain forms of service and experience. Based on the key attribute of “human,” virtual digital humans aim for a high degree of anthropomorphism in their outward appearance and interaction effects. Technologically, the development of digital human video content generation and interaction shows trends of diversification, intelligence, and efficiency, which can trigger users’ sense of intimacy and immersion. Currently, virtual digital humans are mainly divided into non-interactive and interactive virtual digital humans. Interactive virtual digital humans are further divided into human-driven and AI-driven types [10]. The virtual robot products on the market can be classified into two categories: service-type virtual humans and identity-type virtual humans. The former includes industry-specific assistants that replace humans in content production and simple interactions, such as virtual hosts, bank advisors, exhibition guides, and more generalized AI assistants that focus on a sense of companionship. The latter is characterized by a high degree of identity, such as virtual idols and second avatars in virtual worlds. Based on the scholars’ classification above, the virtual digital humans discussed in this study belong to the interactive service-type category and serve as an experiential medium that connects the real rural space with virtual platform spaces, also carrying the task of providing feedback on scenes and platforms [11]. Virtual digital humans are regarded as one of the most popular applications in the field of artificial intelligence and a new frontier of the global digital economy [12]. The business of virtual digital humans mainly focuses on areas like gaming, virtual idols, and brand marketing. Domestic research is primarily concentrated on the media and marketing aspects of virtual hosts and virtual idols. However, these remain superficial categories. The most significant potential productive value of virtual digital humans lies in their ability to become real human resources that serve the development of real-world productivity [13].

2.3. Paradigm shift of rural culture and tourism digital transformation from the perspective of scene theory

As Clark proposed in his urban studies, scene theory emphasizes that spatial shaping, behavioral interaction, and cultural narration are the three core elements of a scene, which play an extremely crucial role in the construction of urban scenes [14]. The construction of rural scenes primarily relies on the layout of physical space, the integration of cultural elements, and the interaction of visitor behaviors to create a tourism experience with local characteristics. However, due to the limitations of fixed geographic space, static cultural resource display, and inadequate infrastructure, traditional rural cultural and tourism scenes have certain limitations in the depth of experience and the breadth of communication [15]. With the introduction of digital technology, rural cultural and tourism scenes have broken through the limitations of physical space, enabling cultural experiences to extend multidimensionally through virtual spaces, augmented reality technologies, and intelligent interactions [16]. Digital culture and tourism not only optimize space shaping and behavioral interactions but also reshape cultural narratives. Digital technology has transformed rural cultural and tourism scenes from static physical spaces to dynamic immersive cultural experiences. Visitors are no longer mere “observers” but “participants” who can interact deeply with the digital scene, further enhancing the immersion of the scene experience [17]. In the framework of scene theory, digital cultural and tourism scenes are not just platforms for information delivery; they are narrative and interactive experiential spaces [18]. In digital cultural and tourism scenes, cultural expression is no longer limited to the fixed resources of offline spaces, but can be infinitely extended through virtual spaces, further breaking the boundaries between physical spaces and digital content. This allows rural scenic spots to add features like virtual tours, intelligent interaction, and dynamic experiences, thereby enhancing the depth and interactivity of cultural communication.

3. Research methodology—Mixed approach of multi-case empirical analysis and semi-structured interviews

3.1. Case selection and research design

This study uses Zhejiang Province as the empirical field, selecting 17 typical rural culture and tourism projects as case samples. These include mountain villages (e.g., Songyang County in Lishui), ancient town scenic areas (e.g., Qiantong Ancient Town in Ningbo), and intangible cultural heritage hubs (e.g., Cao Hui Guan Village in Quzhou) (for case details, see Appendix Table). Case selection follows the principle of differentiation, balancing differences in economic development levels and resource endowments, aiming to fully reflect the diverse pathways of digital transformation in rural culture and tourism. Zhejiang Province, as a pioneer in the construction of "Digital Villages," provides valuable reference and critical insights for other regions.

3.2. Data collection and processing

The research gathers data through two methods: semi-structured interviews and multi-source data verification.

From January to September 2023, in-depth interviews were conducted with 18 practitioners, including 17 government officials and 1 university expert. The interviews focused on three main themes: “operational pain points,” “technology applications,” and “community participation.” The average interview duration was 62 minutes, with 200,000 words transcribed. In addition, policy documents, operational reports, and other materials related to the case projects were collected for cross-validation of the interview conclusions.

Data analysis followed a three-level coding process:

- First-level coding: 58 initial concepts were extracted from the raw data (e.g., “visitor experience,” “community management”).
- Second-level coding: These concepts were grouped into 16 core categories (e.g., “operational pain points,” “community governance”).
- Third-level coding: These categories were integrated into the “Technology-Space-Relations” theoretical model. The coding process was carried out using NVivo software, with coding consistency verified by the Kappa coefficient (Kappa = 0.81).

3.3. Research validity and ethics

To enhance the credibility of the conclusions, the study employed a triangulation strategy: 1. Data cross-validation: Comparing interview, document, and visitor evaluation data. 2. Methodological complementarity: Combining qualitative analysis with quantitative scoring. 3. Researcher triangulation: Two independent coders performed the initial concept extraction, with any discrepancies resolved through group discussion.

The study adhered to academic ethical standards, with all participants signing informed consent forms. Sensitive information was anonymized.

4. Study finds

4.1. The three-dimensional dilemma of rural culture and tourism development

4.1.1. Binary constraints of operational mechanisms and infrastructure

Rural culture and tourism scenic areas, as important carriers for rural cultural revitalization, face multi-dimensional structural contradictions in their operational mechanisms and infrastructure development, as revealed by in-depth research on typical scenic areas in Zhejiang Province (January-September 2023). Interviews with 16 local government officials, scenic area managers, and 1 academic expert identified these challenges.

4.1.1.1. Institutional dilemma of cost-revenue imbalance and fiscal dependence

Rural culture and tourism scenic areas commonly face dual challenges of cost-revenue imbalance and low management efficiency. The research shows that the average annual operational cost-to-revenue ratio of the sample scenic areas is as high as 1.8:1 (Interview K03), with 73% relying on government subsidies (subsidy proportion > 40%) (Interview K04). The geographical marginality leads to poor accessibility, with visitor commuting time being 2.3 times longer than that of urban scenic areas (Interview K08), compounded by seasonal fluctuations (visitor flow differences between peak and off-peak seasons reaching 4-7 times). This exacerbates operational vulnerability. This phenomenon reflects the unsustainability of the traditional “ticket economy + fiscal subsidy” model, and the issue of a single profit model in scenic areas needs urgent resolution.

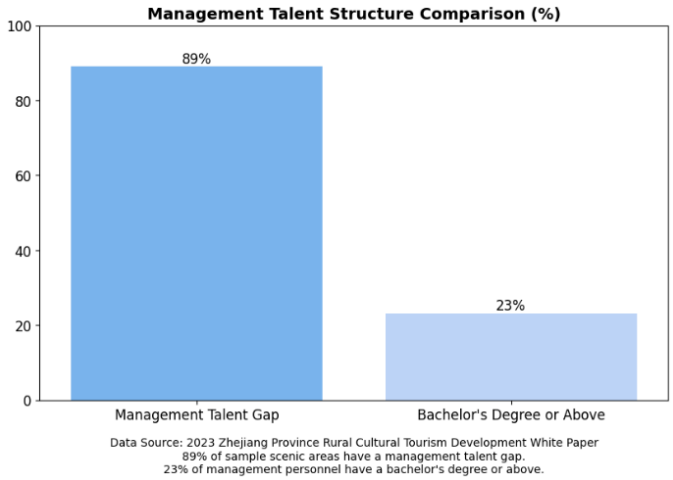

Figure 1. Comparison of management efficiency and talent structure

From a management perspective, 89% of the scenic areas have a shortage of professional talents (with only 23% holding a degree above the undergraduate level) (Interview K04) (see Figure 1). Bureaucratic rigidity leads to insufficient service standardization (67% of tourist complaints involve service issues). A typical example is that facility maintenance response times are 2.5 times the industry average (Interview K04), directly causing a 15% decrease in repeat visitor rates.

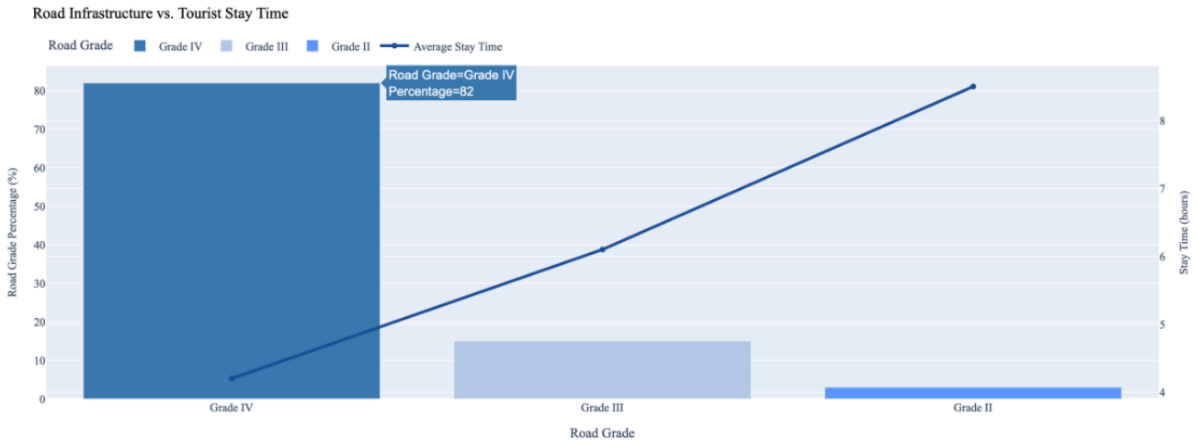

Figure 2. Traffic density map

4.1.1.2. Temporal-spatial discontinuity of infrastructure systems

Analysis of the traffic network density (see Figure 2) shows that the surrounding roads of the sample scenic areas are mainly level-four highways (82% of roads), and the average bus interval is 127 minutes. In the case of Chun'an County, "the supply gap of hotel bed capacity within 15 km of the scenic area is 43%, directly leading to a 0.8-day reduction in the average visitor stay" (Interview K08). This dual constraint of "accessibility-carrying capacity" forms a spatial bottleneck for rural culture and tourism development.

4.1.2. Deterioration of the effectiveness of marketing and communication systems

The healthy development of rural tourism requires scientifically rational marketing strategies and efficient communication methods. However, in the current development of rural tourism, marketing and communication methods remain key bottlenecks that hinder progress. The single nature of marketing methods not only limits the ways tourists access tourism information but also places rural tourism destinations at a disadvantage in the competitive market, necessitating innovation in marketing models to optimize the situation.

4.1.2.1. Structural contradictions of single channels and slow market response

Currently, the marketing of rural tourism still relies heavily on traditional promotional methods. Interviewee K06 pointed out: "Our promotion methods are still primarily posters, billboards, and TV ads. While these methods are effective for older tourists, they have limited appeal to younger groups." Additionally, the rural tourism promotion system is still highly reliant on government-led initiatives, which focus more on policy dissemination than market-driven brand creation. Furthermore, promotional resources are concentrated on short-term festival events, making it difficult to maintain long-term popularity.

4.1.2.2. Technological gap due to disparate digital touchpoints and lack of content innovation

The acceptance of digital marketing content by tourists is influenced by various factors, with interactivity and creativity being key variables [19]. While short videos, social media live broadcasts, and smart recommendation algorithms have gradually changed the way tourists obtain information, the application of digital marketing in rural tourism destinations is still lagging. Some rural tourism destinations have yet to establish systematic new media content operation mechanisms, leading to monotonous communication content. Moreover, due to the limited involvement of interactive design in digital marketing methods, tourists often passively receive information, lacking a sense of participation and immersion.

4.1.3. Dual deficiency in industry ecosystem and brand value

The product ecosystem of rural cultural tourism refers to a system of tourism products formed by integrating various resources with rural culture, natural resources, and local customs at its core, which generates unique attractions. Brand development is a core component of rural cultural tourism, as it not only enhances the market competitiveness of tourist destinations but also increases visitor loyalty and sense of identity. However, the product ecosystem and brand development in rural cultural tourism are facing numerous challenges, mainly reflected in the following aspects:

4.1.3.1. Vulnerability of the industry chain and traditional sales model growth barriers

Rural cultural tourism industries have long depended on single traditional sectors (such as tea leaf picking), making them weak in risk resistance and struggling to generate stable profits. For example, a tea-producing region only focuses on basic tea picking and sales, failing to deeply explore the value of tea culture. Once the core product market fluctuates or the tourist high season ends, the tourist site's income is hard to sustain, highlighting the industry chain's vulnerability. E-commerce resources are not effectively utilized, and data-driven models have not been integrated into the industry ecosystem. Despite being in a region where e-commerce is developed, the use of digital technology for precise marketing and supply chain optimization is lacking, leading to instability in agricultural product supply and limited sales expansion, preventing the formation of a "production–sales–consumption feedback–reproduction" virtuous cycle.

4.1.3.2. Ambiguity in top-level design and weakening of cultural IP in positioning

The branding of rural cultural tourism lacks a unified and scientific top-level design. Some rural cultural tourism projects lack professionalism and systematization in refining the core value of their brands and designing brand visual identity systems. Brand logos and promotional slogans are frequently changed, leading to a vague brand image. As one interviewee stated, "When I arrived in Pingyang, I found that the brand identification for 'Huang Tang' was very weak, with no regional characteristics" (Interview K02).

4.1.3.3. Lack of community participation restricting sustainable brand development

Brand building in rural cultural tourism cannot be achieved without the participation and support of the local community. However, the connection between communities and tourism projects is currently insufficient. During the brand-building process, emotional interactions and connections with residents are overlooked, leading to a weak sense of recognition and belonging among residents towards the local cultural tourism brand. Community management models, such as grid management, have not been fully leveraged in brand construction. There is insufficient communication and collaboration mechanisms between the community and tourism project operators, and the channels for residents to participate in brand development are not smooth, significantly affecting the sustainability of brand construction and community support.

4.2. Transformation logic of digital cultural tourism under scene theory

4.2.1. Theoretical translation: paradigm shift from physical space to digital space

Scene theory emphasizes the interaction between space, behavior, and culture in constructing the social significance of a scene (Clark). Traditional rural cultural tourism scenes are limited by the physical space's fixed nature (such as the layout of ancient villages) and the static nature of cultural displays (such as exhibition panels), leading to short visitor stays and weak emotional resonance. Digital technology breaks this limitation through the following pathways:

4.2.1.1. Dynamic extension of narrative logic and immersion of experience levels

In digital scenes, "context" becomes the core of experience creation. The context is not only a reproduction of the environment but also a dynamic cultural narrative method. It can transport visitors into immersive spaces with high levels of participation and emotional resonance through virtual reconstruction and interactive immersion. For example, digital rural museums use holographic imaging and virtual tour technologies to allow visitors to "enter" historical scenes, interact with virtual characters, and experience traditional handicraft production, thereby strengthening their understanding and immersion in rural culture [20]. Visitor behavior shifts from passive observation to active participation. In digital rural museums, cultural information is conveyed through holograms, dynamic 3D models, virtual tours, etc., allowing visitors to "enter" historical scenes. Through virtual interaction, visitors can engage in more personalized, immersive, and gamified cultural experiences, purchasing rural specialty products, thereby increasing the enjoyment and engagement in cultural consumption.

4.2.1.2. Deconstruction mapping of physical spaces and coupling regeneration of virtual scenes

Digital scenes are not simple replications of physical spaces but instead achieve the reconstruction of cultural symbols and the integration of interaction mechanisms through virtual technology. Digital scenes allow cultural symbols, scene elements, and behavioral experiences from the real world to be digitally reshaped and integrated with the interaction mechanisms of virtual spaces, forming a digital cultural tourism system with multi-level narratives and multi-dimensional interactions. The way scenes are constructed is undergoing profound change, and physical space is no longer the sole carrier of cultural experience; it now forms a "hybrid experience space" with virtual scenes.

4.2.2. Reconstruction of digital space elements: three-dimensional coordination of "technology-space-relationships"

In the context of scene theory, digital spaces exhibit a series of unique and interconnected spatial elements that redefine people's perception and experience of digital spaces.

4.2.2.1. Digital infrastructure construction: enhancement of infrastructure capability

Overall, the construction of digital spaces is a more flexible, dynamic digital domain that combines technology infrastructure, spatial shaping, and social interaction to form a digital ecological system. The construction of digital spaces relies on highly developed digital infrastructure, which not only optimizes the efficiency of information flow but also enhances the stability and sustainability of virtual spaces. Virtual scenes become the environment for user experience, and their construction has shifted from static geographical representation to highly dynamic space shaping. Space is no longer just a physical existence but also a carrier of social and cultural content, where users are no longer passive observers but can actively adjust the environment, influence space operation, and even create new interaction models. This flexibility of scenes enables various cultural experiences like remote socializing, virtual consumption, and digital entertainment to develop concurrently within the same digital ecosystem. Meanwhile, users are no longer traditional real-world individuals but are mapped as digital avatars.

4.2.2.2. Social system reconstruction: capital accumulation in virtual communities

Social interaction, content creation, and economic systems together form the core ecosystem, making virtual spaces dynamic social environments. The construction of this social system depends not only on the immediacy and diversity of information dissemination but also on the stability of user identities and the accumulation of social capital in the virtual environment. Users interact through digital identities, extending social interactions from offline interpersonal relationships to highly virtualized community relationships. The development of digital technology has broken the centralized structure of traditional content production, making User-Generated Content (UGC) a key element in constructing virtual scenes. User creativity is unleashed in the digital environment, where spatial experiences gradually shift from passive acceptance to active creation. Meanwhile, content creation and social systems interact, transforming user behavior from personal expression into cultural flow and value recognition within virtual spaces. The economic system provides operational support, ensuring that content creation and social interaction form a sustainable cycle. The virtual economy system facilitates economic returns for user creations through digital asset

transactions and value transformation mechanisms, forming a virtuous cycle of "creation–transaction–profit–recreation," driving the continued growth of the digital ecosystem.

4.3. Digital technology empowerment in rural cultural tourism: innovative pathways

As rural cultural tourism continues to develop, digital technology is becoming a key driver in enhancing community participation, creating an organic empowerment system.

4.3.1. Input layer: technological foundation and resource transformation

Technologies like VR and AR break the boundary between reality and the virtual world, offering new dimensions for constructing rural cultural tourism scenarios. Unlike traditional static displays, VR technology allows visitors to immerse themselves in specific cultural scenes, enhancing the authenticity and emotional engagement of the experience. AR technology overlays virtual information on the real environment, providing real-time cultural interpretations during the tour. These technologies not only improve the visualization of cultural information but also make the cultural experience more interactive and multi-layered, offering new narrative logic and sensory experiences for rural tourism. The digital transformation of cultural resources is crucial for the long-term development of rural cultural tourism.

Rural culture's core value lies in its unique historical accumulation and local characteristics, and the digital transformation process reconstructs and modernizes these cultural resources. Methods such as field surveys, archival sorting, and oral history collection are used to systematically store rural cultural information, providing a foundation for future digital development. Multi-modal expression technologies, such as audio, video, animation, and 3D modeling, allow for immersive displays of rural culture. For example, traditional operas and folk tales can be presented through animated shorts or virtual studios, enabling visitors to experience the culture firsthand in virtual environments. Additionally, digital humans play an essential role in cultural transmission, acting as cultural guides and demonstrating intangible heritage crafts, and using AI-driven interactive modes to engage with visitors, enhancing the vitality and immersion of cultural communication.

4.3.2. Transformation layer: embedding technology and scene iteration synergy

4.3.2.1. Digital twin-driven innovative practice map

Under the Digital China strategy, rural cultural tourism is undergoing a paradigm shift from "technology embedding - scene reconstruction - value addition." Based on research from 6 cities and 11 digital demonstration projects in Zhejiang, this study constructs an innovative path model of "three-tiered empowerment."

A digital twin is a virtual model of a physical entity created through digital technology to simulate and optimize its operational state. In rural cultural tourism, digital twin technology can extend the cognitive duration of visitors through VR and AR technologies. For example, the Ningbo Cicheng Ancient County project used a VR time-space tunnel to extend visitors' cultural engagement time from 27 minutes to 2.1 hours, significantly improving their cultural experience (Interview K02). Similarly, the AI tour guide system in Wenzhou Cangnan increased visitor conversion rates by 19%, highlighting the catalytic effect of embodied technology on deepening the experience (Interview K05). The fusion of virtual and physical elements creates a new dimension of experiences. For example, the immersive theater practice in Quzhou Caohui Village is paradigm-defining: using motion capture and holographic projection technology, visitor participation reached 73%, 4.2 times higher than traditional performances (Interview K07). Its "scene response algorithm" dynamically adjusts the narrative pace based on real-time visitor density (greater than 2 people per square meter), optimizing service supply. This technological application not only increases visitor participation but also optimizes the service efficiency of scenic spots. The digital ecosystem refers to an ecosystem constructed through digital technologies, encompassing digital infrastructure, content, services, and more. For example, the digital twin platform of Anji Yucun generated significant spillover effects: the cultural dissemination radius expanded to 42 countries, and online sales of derivative products accounted for 37% (Interview K15). The "Cloud Village" project in Songyang created a digital shared prosperity effect, increasing per capita income of surrounding farmers by 8,200 yuan, demonstrating the multiplier effect of "digital catalysts" (Interview K16).

4.3.2.2. Cultural gene coding: narrative reconstruction in virtual studios

Virtual studios, through digital technology, overcome geographical limitations to offer dynamic cultural experiences. In the design process, rural natural landscapes are used as the basis for constructing virtual scenes, which blend the distinctive characteristics of rural areas. By recreating the appearance of ancient village buildings and employing virtual tour technologies, visitors can "walk into" each building to explore its history and cultural connotations. The construction of virtual studios relies on core technologies such as high-precision 3D modeling, AI interactive features, and real-time rendering, providing a vivid medium for the digital expression of rural culture. These technologies not only enhance users' sense of presence but also encourage the transformation of cultural content from static to interactive, with visitors becoming active participants in shaping the experience. Cultural storytelling should not just be about information transmission but also emphasize deep participation and emotional resonance. For example,

when simulating traditional dragon and lion dance performances, digital humans precisely replicate the dancers' movements and combine them with virtual rural music and folk elements to form an immersive cultural experience. In virtual rural food festivals, visitors can simulate making traditional pastries through VR devices, shifting from passive observers to active participants.

From an industrial development perspective, technological innovation drives regional economic growth and forms new industry chains for deep integration with the rural economy. For example, using real-time rendering technology in virtual studios can bring ancient operas to life with modern digital techniques. At the same time, live-streaming through virtual studios spreads rural cultural activities to a broader audience, attracting more potential visitors and optimizing the rural cultural tourism industry ecosystem. This contributes to the shaping of rural tourism brands and supports the sustainable development of rural cultural tourism industries. In the future, virtual studios will play a deeper role in rural cultural tourism scenarios, integrating AI, blockchain, and digital twin technologies to create more interactive and intelligent cultural tourism ecosystems.

4.3.3. Output layer: cultural value-addition and industry synergy effects

The digital expression of culture, technology-driven immersive scene construction, and optimization of intelligent service systems together form a new value chain in rural cultural tourism, creating a dynamic cycle system of "cultural experience - economic benefits - social participation." In this process, the digitalization of rural culture is not just a presentation of traditional cultural resources but also a deep re-creation and brand operation of cultural values. Elements such as rural history, folk culture, and intangible heritage crafts are digitally transformed and further developed into widely disseminated cultural symbols, providing more possibilities for the commercialization of cultural content. Through precise cultural IP development, the methods of communication for rural cultural tourism have become more diverse. Digital technology not only reshapes the expression of rural culture but also gives birth to new industrial forms. With the continuous improvement of digital infrastructure, rural cultural tourism's profit model is gradually evolving from offline ticketing and traditional tourism consumption to an integrated online-offline industry model. For example, virtual rural experiences, smart tours, and VR immersive cultural interactions not only extend the length of visitors' experiences but also enhance the market appeal and monetization ability of rural tourism products.

In the digital cultural tourism system, the role of rural residents is transforming from traditional providers of tourism resources to co-creators of industries (see Figure 3), contributors to cultural content, and beneficiaries of the digital economy. This transformation not only enhances the overall economic vitality of rural society but also promotes the self-construction and active inheritance of local cultures. Digital tools such as smart voice recording and image capturing enable villagers to upload local cultural stories and intangible heritage displays, realizing a community-driven cultural communication model. Furthermore, the digital development of rural cultural tourism is also driving innovation in rural governance models. For example, the data analysis function of smart tourism platforms can accurately predict tourist traffic and optimize scenic spot operations, improving visitor capacity and reducing ecological pressure on rural areas. Additionally, big data analysis of rural tourism can help local governments formulate precise cultural tourism policies.

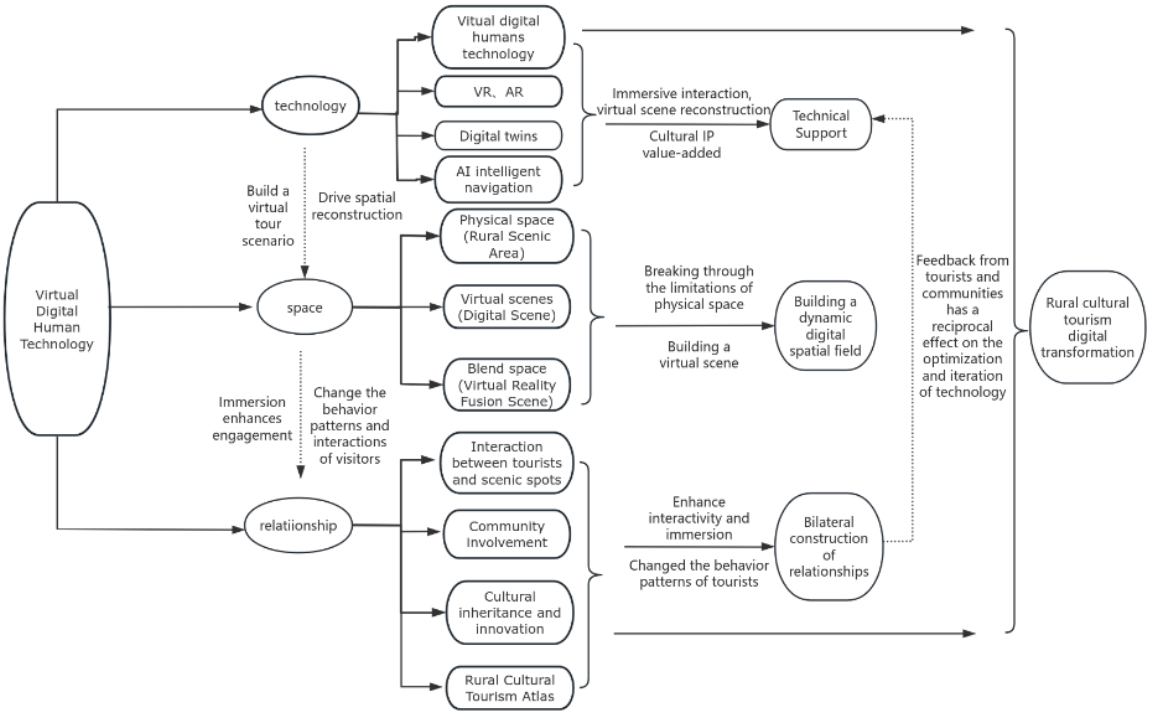

Figure 3. Digital transformation process flowchart of rural cultural tourism

5. Conclusion and outlook

This study, based on the theory of scenes, systematically explores the application of virtual digital human technology in rural cultural tourism and its digital transformation path. Through a multi-case analysis of digital demonstration projects in Zhejiang Province, the research finds that the traditional model of "ticket economy + financial subsidies + offline sales" can no longer meet the development needs of the modern cultural tourism industry. Virtual digital human technology provides a new development path for rural cultural tourism. Specifically, virtual digital humans not only optimize cultural narratives, enhancing visitors' cultural experiences and emotional resonance, but also, through technologies such as digital twins, virtual studios, and AI intelligent guides, promote the visual and interactive expression of rural cultural resources, improving the dissemination efficiency and brand value of rural cultural tourism. Additionally, the application of digital technologies can, through community co-creation models, transform rural residents from traditional tourism resource providers to cultural co-creators and industry participants, promoting the lively inheritance and shared development of rural culture.

The research further finds that the digital development of rural cultural tourism is evolving from a single sightseeing model to a complex and sustainable industrial ecosystem, forming a "technology-space-relationship" three-dimensional collaborative model. The deep integration of virtual digital human technology promotes the expansion of rural economy by linking rural cultural tourism with industries such as cultural creation, e-commerce, smart agriculture, and intangible cultural heritage protection. At the same time, the application of smart tourism platforms and big data analytics provides precise decision support for rural social governance, optimizes scenic spot management, enhances visitor capacity, and reduces the impact on the rural ecology, further driving the high-quality, intelligent development of rural cultural tourism.

Although the application of virtual digital human technology in rural cultural tourism shows broad prospects, there are still some issues that need to be addressed. Future research can further explore how to lower the threshold for the application of digital technologies and promote the inclusive development of rural cultural tourism. Furthermore, with the continuous development of metaverse technology, virtual digital humans are expected to play a role in a broader range of cultural scenarios, further expanding the digital boundaries of rural cultural tourism. Virtual digital human technology provides new possibilities for the digital transformation of rural cultural tourism. Future development needs to be promoted collaboratively at multiple levels, including technology, policy, and community participation, to achieve high-quality development and cultural revitalization of rural cultural tourism.

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Appendix

Appendix Table. Rural cultural-tourism digital transformation cases in Zhejiang

ID	Gender	Interview Date	Administrative Unit
K01	Female	2023.1.19	Yangjiamen Community, Tongxiang City, Jiaxing
K02	Male	2023.2.20	Zhejiang University
K03	Male	2024.3.22	Ninghai County, Ningbo City
K04	Female	2024.4.23	Baishi Town, Quzhou City
K05	Female	2023.4.24	Cangnan County, Wenzhou City
K06	Male	2023.4.25	Shiba Li Village, Jinhua City
K07	Female	2023.5.28	Caohuiguan Village, Quzhou City
K08	Female	2023.6.29	Chun'an County, Hangzhou City
K09	Male	2023.6.30	Tonglu County, Hangzhou City
K10	Female	2023.7.01	Deqing County, Huzhou City
K11	Male	2023.7.15	Longyou County, Quzhou City
K12	Male	2023.7.04	Shengzhou City, Shaoxing
K13	Female	2023.7.05	Wuyi County, Jinhua City
K14	Male	2023.8.06	Haiyan County, Jiaxing City
K15	Male	2023.8.07	Anji County, Huzhou City
K16	Female	2023.8.08	Songyang County, Lishui City
K17	Female	2023.9.11	Tiantai County, Taizhou City
K18	Female	2023.9.12	Pingyang County, Wenzhou City

Note: The research strictly follows academic ethics standards. All interviewees have signed informed consent forms, and sensitive information has been anonymized.