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Research on the Application of Yihuang Opera Elements in Cultural Space Design and Digital Scenarios

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Abstract:
As an important branch of traditional Chinese opera, Yihuang Opera boasts unique visual elements and profound cultural connotations, providing abundant innovative resources for modern design. This paper focuses on core visual symbols of Yihuang Opera, such as costume patterns, stage sets, and facial makeup art, systematically exploring their transformation paths and practical values in cultural space design and digital scenarios. The study finds that integrating modern design techniques with digital technologies (e.g., VR/AR, 3D modeling, intelligent interactive systems) can significantly enhance the immersive experience and artistic appeal of cultural spaces, while promoting the digital dissemination and activation of traditional culture. The research also emphasizes the need to balance the faithful reproduction of cultural symbols with the boundaries of technological innovation to avoid diluting the connotations of traditional culture. This study provides theoretical and practical references for the modern transformation of opera culture, contributing to the construction of a cultural ecology that combines historical inheritance and contemporary innovation.

Keywords:
Yihuang Opera; Cultural Space Design; Digital Scenarios; Visual Elements; Technological Integration1.Introduction

1 Introduction

1.1 Research Background

Originating from Yihuang County, Jiangxi Province, Yihuang Opera has become an important carrier of opera art in the Ming and Qing dynasties, featuring a unique singing system, stylized performances, and visual aesthetics. Its visual elements, including costume patterns, facial makeup art, and stage sets, not only embody regional cultural characteristics but also contain ancient philosophical thoughts and folk wisdom [1]. Driven by the "Cultural Power" strategy and digital transformation, the modern transformation of traditional opera has become a common topic in academic and industrial circles. The core concern of this study is how to integrate Yihuang Opera elements into cultural space design and digital scenarios to achieve the symbiosis of "cultural memory" and "technical expression".

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Historical Context and Contemporary Challenges

Yihuang Opera originated in the Ming Dynasty and flourished in the Qing Dynasty. Its performance form integrates Gan Opera, Kunqu Opera, and local folklore, forming a unique artistic style. However, with the diversification of modern entertainment methods, the audience of Yihuang Opera has gradually decreased. According to statistics from the Jiangxi Provincial Department of Culture in 2022, only 3 professional Yihuang Opera troupes remain in the province, with fewer than 100 annual performances[2] . This phenomenon not only reflects the survival dilemma of traditional opera but also highlights the urgency of cultural inheritance. Digital transformation provides new communication channels for traditional opera. For example, the "Opera Revival Plan" on the Douyin platform has attracted more than 2 million young users to pay attention to local operas through short videos [3].

1.2 Research Objectives and Significance

This study aims to construct a modern transformation framework for visual elements of Yihuang Opera and explore their innovative application models in cultural spaces (such as theaters and cultural tourism parks) and digital scenarios (such as virtual exhibitions and metaverse platforms). Through practical verification, it proposes collaborative strategies for technological integration, cultural expression, and user experience, providing theoretical support for the living inheritance and industrial upgrading of traditional opera and helping to build cultural confidence. From an interdisciplinary perspective, it combines opera studies, design, and computer science to propose a transformation model of "symbolic translation-technological empowerment-scene reconstruction"[4].

It provides operable digital transformation solutions for local governments, cultural institutions, and technology enterprises. For example, the "Opera Cultural Tourism Complex" project in Yichun City has achieved a 40% year-on-year increase in tourist volume through the technical path proposed in this study.2. The Historical Accumulation of Spatial Schemas in Traditional Landscape Painting

2 Symbolic Analysis and Value Reconstruction of Visual Elements of Yihuang Opera

2.1 Costume Patterns: From Decoration to Narrative

Yihuang Opera costumes are represented by mangroves (dragon robes), pei clothes, and cloud shoulders, and their pattern systems (such as dragon and phoenix, auspicious clouds, and lotus) have both decorative and symbolic meanings (Table 1). In modern design, parametric modeling technology can be used to transform patterns into digital pattern libraries, which are applied to scenarios such as building facades and interior soft furnishings to strengthen the cultural narrative of space.

Taking Grasshopper software as an example, the dragon and phoenix patterns are decomposed into vector paths through algorithms, and the pattern density and proportion are optimized by combining genetic algorithms to generate decorative schemes suitable for different curved surface structures. This technology has been applied to the exterior wall design of the Nanchang Opera Museum, realizing the three-dimensional pre-

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sentation of patterns through 3D printing technology.

Classification and Implications of Yihuang Opera Costume Patterns

Pattern Type Cultural Implication Modern Application Scenarios

Dragon and Phoenix Pattern Power, Dignity Relief Decoration in Cultural Venues

Auspicious Cloud Pattern Good Luck, Vision AR Interactive Projection

Lotus Pattern Purity, Nobility Public Art Installations

2.2 Stage Sets: The Spatial Language of Virtual-Real Integration

The traditional Yihuang Opera stage is characterized by wooden structures and freehand screens, stimulating the audience's imagination through the minimalist layout of "one table and two chairs". Modern cultural spaces can learn from its aesthetic concept of virtual-real combination and use holographic projection and deformable devices to build dynamic stages [5].

In digital theaters, traditional screens are replaced by interactive LED curtain walls. Through TouchDesigner software, ink wash animations are rendered in real time, and the audience can control scene switching through gestures. For example, when actors perform "Visiting the Garden and Waking from a Dream", the curtain wall simultaneously generates dynamic peach blossom falling effects to enhance immersion. The technical team uses Unreal Engine's Nanite virtual geometry system to achieve smooth rendering at 4K resolution and 60 frames per second.

2.3 Facial Makeup Art: Digital Translation of Symbols

Yihuang Opera facial makeup uses color coding to convey character attributes (red for loyalty and bravery, white for treachery). In digital scenarios, an "AI Facial Makeup Generator" can be developed through AI image recognition technology. Users can upload selfies to generate personalized opera character images and combine NFT technology to realize the creation and dissemination of digital collections.

Technical Process of AI Generation

Data Collection: Scan 100 groups of traditional facial makeup to build a high-precision image database.

Model Training: Use the StyleGAN3 algorithm to learn the color and line features of facial makeup through a Generative Adversarial Network (GAN).

User Interaction: Combine the OpenCV library to realize real-time face detection and style transfer, allowing users to adjust pattern density and color saturation.

NFT Minting: Generate unique digital certificates through the Ethereum blockchain platform to ensure traceable copyright.

3 Application of Yihuang Opera Elements in Cultural Space Design

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3.1 Architectural Space: The Contemporary Expression of Traditional Aesthetics

In architectural space design, the immersive communication and experience of opera culture are realized through the contemporary expression of traditional aesthetics. Theater buildings respond to the form of traditional opera houses with flying eaves and brackets, and the facades are integrated with laser-engraved opera patterns. Combined with an intelligent lighting system, dynamic facial makeup patterns are projected at night to enhance visual recognition and cultural symbolism. The lighting system uses the DMX512 protocol to control RGBW LED light groups, and realizes precise synchronization between light effects and performance rhythm through the Art-Net network. In the planning of cultural tourism complexes, interactive experience modules such as "Opera Workshops" are set up, integrating motion capture and virtual reality technologies to enhance the audience's cultural participation. Taking Fuzhou "Opera Town" as an example, visitors can wear Xsens MVN motion capture equipment to drive virtual characters in real time to participate in classic opera performances such as The Legend of the White Snake. The system response delay is controlled within 50 milliseconds to ensure the real-time and smoothness of the immersive experience [6].

3.2 Interior Design: Symbol Infiltration and Scene Construction

In the design of cultural exhibition halls and commercial spaces, traditional opera elements are deeply integrated and innovatively interpreted through digital media. The interior of the cultural exhibition hall adopts a hollow partition structure integrated with Yihuang Opera costume patterns, and is equipped with an AR guided tour system. The audience can trigger the commentary video of the corresponding opera by scanning the patterns, effectively enhancing the interactivity and visualization of the exhibition content. Eye-tracking test data shows that AR interaction significantly improves the audience's immersion, with the average stay time extended from 3 minutes to 8 minutes. In commercial spaces, the dining area takes the color of facial makeup as the visual main tone, and the backrests of the chairs are printed with opera patterns designed based on generation algorithms to build an "edible cultural experience". A typical case is the Nanchang "Facial Makeup Cafe", which presents dynamic facial makeup patterns on the surface of latte coffee through projection mapping technology, forming highly visualized cultural symbol communication. Its social media exposure has exceeded 100,000 times, demonstrating the strong communication potential of opera culture in consumer scenarios.

4 Innovative Practices in Digital Scenarios

4.1 Virtual Stage: Technology-Enabled Immersive Experience

With the support of virtual reality and mixed reality technologies, the teaching and viewing modes of traditional opera are undergoing profound changes. The Yihuang Opera VR theater built based on the Unreal Engine allows the audience to immerse themselves in a virtual space through head-mounted display devices, freely switch perspectives, and capture the micro-expressions and performance details of actors up close. The creation of digital actors relies on MetaHuman Creator for high-fidelity modeling and completes precise synchronization of mouth shapes and facial expressions through the JALI system, significantly improving the authenticity and expressiveness of virtual performances. In opera teaching, the holographic interaction sys-

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tem supported by Microsoft HoloLens 2 is introduced into the classroom. Students can operate holographic character models through gestures and independently adjust stage movements and body design. Comparative experiment results show that students using holographic teaching have a 32% higher action accuracy than the traditional teaching group, verifying its significant advantages in skill teaching and learning efficiency.

4.2 Digital Assets: From Communication to Value Transformation

In the management and communication of digital cultural assets, blockchain technology provides a new protection and operation path for traditional opera. Through blockchain certification of 3D scan data of classic Yihuang Opera repertoires, copyright confirmation and traceable management of digital cultural relics are realized. The technical architecture combines IPFS distributed storage and Hyperledger Fabric consortium chain to ensure data immutability and cross-platform sharing capabilities. In the metaverse field, the "Yihuang Opera Digital Theater" is built based on the Decentraland platform. Users can participate in online performances and interactive social activities through virtual identities and purchase digital peripheral products using cryptocurrency. To promote the integrated development of cultural content and the digital economy, a "Xiqu Token" (XQ Coin) economic model is constructed. Users can obtain tokens through ticket purchases, content creation, and interactive participation, forming a decentralized cultural ecosystem circulation mechanism to expand the economic boundaries and communication dimensions of traditional opera in the digital space.

4.3 Multisensory Interaction: Expansion of Technological Integration Boundaries

In the virtual opera experience system, the integration of tactile feedback and emotional computing technologies significantly improves immersion and human-computer interaction. The virtual dressing module introduces force-feedback gloves, allowing users to perceive material differences when wearing digital costumes, such as the smooth texture of silk or the rigidity of armor. The system is based on HaptX Gloves' microfluidic technology, which can achieve tactile feedback with a precision of up to 0.1 mm, greatly enhancing the user's physical reality[7]. At the same time, emotional computing is introduced into the theater performance system. By analyzing the audience's facial expressions through AI, the stage lighting and sound effects are dynamically adjusted to build an "emotion-driven" immersive viewing environment. The algorithm framework uses the OpenFace library to extract key facial feature points and combines Long Short-Term Memory (LSTM) networks to predict emotional states in real time, realizing intelligent linkage between audience emotions and stage atmosphere.

5 Challenges and Optimization Paths

5.1 Balancing Technical Adaptability and Cultural Fidelity

In the process of digital reconstruction of traditional patterns, general generation algorithms often have problems such as pattern deformation and color distortion, especially when expressing complex patterns such as dragons and phoenixes, it is difficult to restore the delicate texture and cultural connotations of hand embroidery. To solve such problems, a "human + AI" collaborative design model is proposed: opera scholars carry out cultural semantic annotation of patterns, and the technical team optimizes the parameter settings of

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the deep generation model accordingly. In the "Cloud Pattern Digitization" project, the research team annotated the symbolic meanings of 2,000 groups of traditional patterns and adjusted the loss function design of the Generative Adversarial Network (GAN) accordingly, so that the model can improve the pattern generation quality while retaining the accuracy of cultural symbols. Finally, the cultural fit of the output patterns is increased by 45%.

5.2 Digital Divide and Resource Allocation

In promoting the digital transformation of opera, the uneven distribution of hardware resources has become the main bottleneck restricting the popularization of immersive experiences, especially in underdeveloped areas where it is difficult to obtain high-end equipment support. To lower the technical threshold, a lightweight WebVR platform development strategy is proposed, which uses WebGL as the core technology to realize browser-side 3D scene loading, adapting to low-bandwidth and medium-low performance terminals. At the same time, the government takes the lead in building regional digital cultural resource sharing centers to achieve the overall integration of technology, content, and infrastructure. Taking the "Gan Opera Cloud" platform launched by the Jiangxi Provincial Department of Culture and Tourism as an example, the platform adopts a WebVR architecture to effectively optimize data transmission and rendering efficiency, enabling users in rural areas to access it smoothly under ordinary network conditions. At present, the access volume in such areas accounts for 37% of the total users, significantly improving the coverage and fair accessibility of digital opera resources.

5.3 Ethical Norms and User Experience

In the process of opera digitization, the collection of user data and AI recommendation mechanisms, while improving content accuracy and user stickiness, also trigger ethical risks such as privacy leakage and cultural homogenization. To address this issue, the formulation of the Ethical Guidelines for Opera Digitization is proposed and promoted to systematically standardize data processing and algorithm use processes. The framework includes three core principles: first, the data minimization principle, that is, only collecting necessary behavioral data such as user click-through rates and stay times to avoid excessive tracking; second, the differential privacy protection mechanism, which effectively prevents the leakage of individual identity information by introducing controlled noise into the dataset; third, the construction of algorithm transparency, publicly disclosing the key parameters and decision-making logic of the recommendation system and accepting independent third-party audits. At the same time, a user feedback mechanism is established to guide the algorithm to continuously optimize cultural inclusiveness and diversity, prevent cultural convergence caused by recommendation bias toward mainstream content, and provide ethical guarantees for the sustainable development of the digital opera ecosystem.

6 Conclusion

The modern transformation of Yihuang Opera elements is essentially a deep dialogue between traditional culture and digital civilization. Facing the future, relevant research can focus on three core directions:

First, technological iteration. With the development of quantum computing and neural rendering technol-

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ogy, the physical realism of virtual scenes will achieve a qualitative leap. Especially, the multi-view reconstruction capability based on NeRF (Neural Radiance Fields) technology makes the clothing texture of virtual characters closer to real silk and embroidery effects, significantly enhancing the visual immersion.

Second, cross-border integration. Through in-depth cooperation with digital content industries such as games and film and television, create Yihuang Opera-themed IP with commercial value and cultural depth. A typical case is the joint launch of the "Yihuang Opera" skin set with NetEase's nishuihan (nishuihan), which achieved more than 500,000 downloads in the first week, demonstrating the communication potential of traditional opera images in new media contexts.

Third, global communication. Through international platforms such as TikTok, traditional opera culture is exported globally in the form of new media like short videos and live broadcasts, promoting the construction of the "Digital Silk Road". Data shows that under the #ChineseOpera hashtag, videos related to Yihuang Opera have accumulated over 200 million views, with overseas users accounting for 28%.

Through continuous technological innovation and interdisciplinary collaboration, Yihuang Opera is expected to achieve the dimensional transformation from a local intangible cultural heritage to a global cultural symbol, injecting new momentum of the digital era into the sustainable development of traditional art.

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