

Research on Digital Cultural and Creative Design and Interactive Experience of Haikou Qilou Old Street Architecture Culture Empowered by Metaverse Technology

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Abstract: This article studies the digital cultural and creative design and interactive experience of Haikou Qilou Old Street's architectural culture empowered by metaverse technology, and constructs a full process technical system of "digital element modeling cultural and creative design experience landing". By deconstructing the architectural elements of the arcade, transforming regional symbols, and constructing a three-dimensional model, extracting core IP symbols, and dividing digital collections and other carrier types; Design an immersive interactive logic of "scene path feedback", build a multimodal technology fusion architecture and a "three-dimensional nine item" quantitative indicator system, suitable for online, offline, and mobile landing scenarios. Digital replication and cultural and creative transformation of arcade architectural culture provide technical support for the digital inheritance of historical architectural culture.

Keywords: Metaverse technology empowerment; Haikou Qilou Old Street Architectural Culture; Digital cultural and creative design and interactive experience

DOI:10.12417/3029-2344.25.08.014

Introduction

The architectural culture of Haikou Qilou Old Street carries the historical and cultural fusion of Nanyang and Lingnan styles, but its structural characteristics and regional symbol digital transformation are insufficient. Metaverse technology provides a new path for the digital transformation of cultural resources, enabling immersive presentation and interactive dissemination of architectural culture. Combining the core requirements of digital cultural and creative design and interactive experience, with arcade architectural culture as the research subject, a layered practice is carried out through element modeling, cultural and creative design, and experience optimization to solve the problems of low efficiency in cultural transmission and single experience in traditional inheritance models, actively exploring feasible paths for deep integration of historical architectural culture and digital technology.

1. Modeling of digital elements in architectural culture

1.1 Deconstruction of the structural elements of arcade buildings

Using the arcade architecture as the core carrier, deconstruct the structural elements of the architectural culture of Haikou's arcade old street, and construct a three-dimensional deconstruction framework of "structural system decorative system spatial system". The structural system focuses on the iconic colonnade structure, wall structure, and roof structure of Haikou arcade. The colonnade structure extracts parameters such as column spacing, column height, and column pattern from the bottom level arcade. The traffic function is adapted to the column spacing and commercial bottom level of Haikou arcade, with values ranging from 3-4 meters; Disassemble the wall structure and sort out the unique roof structures of Haikou arcade, such as the blue brick masonry and the connection between the wall and the colonnade. For the cultural expression carrier of Haikou arcade architecture, extract elements such as decorative system exterior window lintel lines, balcony railing reliefs, mountain flower wall plaster, as well as internal beam frame wood carving, door and window carving, etc., to clarify the distribution position and

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Project: 2025 Haikou Municipal Philosophy and Social Sciences Planning Project "Digital Cultural and Creative Design of Haikou Arcade Old Street Combined with Metaverse Technology" (Project No.: 2025-ZCKT-102)

technological characteristics of various decorations in Haikou arcade architecture.

1.2 Regional symbol number conversion

The transformation of regional symbol numbers focuses on the characteristic symbols in the architectural culture of Haikou Qilou Old Street, and establishes a technical process of "symbol screening feature quantification format adaptation". Selecting symbols based on the regional cultural connotations carried by the architecture of Haikou's arcade buildings, locking in symbols such as the "Hui" character pattern on window decorations, the curved outline of mountain flower walls, the rammed earth texture on wall surfaces, and the font on door lintels and plaques that are indicative of Haikou's arcade culture^[1]. Using computer vision technology to quantify features, contour feature point collection and parameter extraction are performed on the selected Haikou arcade symbols. Geometric pattern coordinates, distances, and other parameters are obtained through edge detection algorithms. Curve fitting technology is used to quantify curvature and arc length data for contour modeling. Texture texture granularity and contrast parameters are extracted through grayscale analysis to construct a Haikou arcade regional symbol feature database.

1.3 Application of 3D Space Modeling

1.3.1 Data preprocessing stage

Using laser scanning technology to collect point cloud data of Haikou arcade buildings, the sampling density is controlled at 5000-8000 points/m². After noise filtering and coordinate calibration, a millimeter level accuracy three-dimensional point cloud model of Haikou arcade buildings is generated. At the same time, the size, material and other data in the form elements are integrated, and a modeling data association library is established. Modeling is carried out in stages according to the "main structure decoration details spatial scene". The main structure is based on point cloud data and form parameters, and core component models such as Haikou arcade colonnades, walls, and roofs are built. Component attributes are associated through parametric modeling techniques; The decorative details are imported into digital Haikou arcade regional symbols, and UV unfolding technology is used to attach the symbol texture to the surface of the components. Displacement mapping is used to restore the three-dimensional effect of relief decoration.

1.3.2 Optimization and adaptation stage

In response to the demand for digital cultural and creative interaction, LOD technology is used to divide the Haikou arcade model into high, medium, and low precision levels. High precision models (500000 to 800000 surfaces) are applied in static cultural and creative displays, medium precision models (200000 to 300000 surfaces) are applied in simple interactions, and low precision models (50000 to 100000 surfaces) are adapted to mobile devices; By removing redundant surfaces, compressing textures, and other methods to achieve lightweight processing, the loading efficiency of different terminal models is guaranteed.

2. Metaverse Digital Cultural and Creative Design

2.1 Architectural IP carrier

Build an architectural IP carrier based on the core elements of Haikou Qilou Old Street's architectural culture, and establish a three-dimensional design system of "IP symbol extraction carrier type classification cultural attribute implantation". Based on the deconstruction of the architectural elements of the arcade and the digital transformation of regional symbols, IP symbols are extracted, and core symbols including colonnade shapes, mountain flower wall contours, window decoration patterns, and plaque fonts are identified and integrated to form a recognizable prototype of Haikou arcade architecture IP. The prototype retains the spatial characteristics of the arcade's "commercial space below and residential space above" and the fusion imprint of Nanyang culture.

The classification of carrier types covers core forms including digital collectibles, virtual scene components, and cultural and creative interactive props. Digital collectibles present the three-dimensional decoration details of

arcade buildings, and high-precision models are used to restore process features such as reliefs and plaster sculptures; Split virtual scene components according to the functions of arcade space, including colonnade modules, wall modules, roof modules, etc., to adapt to the modular construction of metaverse scenes; Combining cultural and creative interactive props with the commercial and cultural attributes of the arcade, design virtual props with functional use to carry the cultural connotation of the arcade commercial port. By embedding cultural attributes through symbol nesting and functional associations, digital collections incorporate the logic of arcade building construction into model details. The size ratio of virtual scene components follows the original shape parameters of the arcade^[2]. The cultural and creative interactive prop function is set to correspond to the historical usage scenarios of the arcade, ensuring that various carriers not only meet the visual needs of digital cultural and creative design, but also accurately convey the architectural culture of Haikou's arcade old street.

2.2 Immersive interactive logic

Design immersive interactive logic around the experiential needs of Haikou Qilou Old Street architectural culture, and construct a closed-loop system of "scene construction interaction path feedback mechanism". Based on the three-dimensional space modeling results of the arcade, a scene is constructed to restore the overall style of the arcade old street and the internal space of individual buildings. The scene elements include arcade colonnades, street interfaces, decorative details, and cultural scene restoration. The spatial layout follows the original street and alley texture and architectural layout rules of the arcade. According to user experience goals, it is divided into cultural cognition path, exploration experience path, and creative participation path. The interaction path is set. The cultural cognition path triggers a cultural information pop-up window by clicking on the arcade building component, and the pop-up window content is associated with the historical background and technological characteristics of the component; Explore the experience path setting space roaming function, where users can freely move between the internal and external scenes of the arcade through perspective control, and set key information trigger points for arcade culture at path nodes; The creation participation path opens up the virtual component editing function, allowing users to conduct secondary design based on the arcade IP symbol, and the design results retain the core genes of arcade culture. The feedback mechanism adopts a multi sensory feedback fusion method, and visual feedback presents interactive results through changes in the state of scene elements. For example, clicking on window decoration patterns triggers dynamic lighting effects, forming an immersive interactive experience logic deeply bound to Haikou arcade architectural culture.

2.3 Cultural and creative twin realization

The cultural and creative twin is based on the architectural and cultural digital assets of Haikou Qilou Old Street, and a technical process of "digital asset integration twin model construction dynamic adaptation optimization" is established. The integration of digital assets includes deconstruction data of arcade form, digital achievements of regional symbols, 3D spatial modeling files, and IP carrier design resources. A unified asset classification standard is established, and resources are archived according to building structure, decorative elements, cultural symbols, and IP carriers. The archived data is associated with arcade cultural attribute tags to ensure accurate asset retrieval^[3].

Using digital twin technology to construct twin models, the structural features, decorative details, and cultural information of physical arcade buildings are mapped to virtual spaces. The models include geometric twin layers, physical twin layers, and cultural twin layers. The geometric twin layer reproduces the three-dimensional form and size parameters of the arcade building, the physical twin layer simulates the material characteristics and mechanical response of building components, and the cultural twin layer embeds information such as the historical evolution, craftsmanship, and cultural connotation of the arcade building.

Dynamic adaptation optimization focuses on the application requirements of metaverse scenarios, dynamically associating twin models with physical arcade buildings through real-time data synchronization. In response to the iterative requirements of cultural and creative design scenarios, it supports parameterized modification and element

replacement of twin models, while preserving the core characteristics of arcade culture during the modification process; Based on user interaction data, adjust the presentation details of the model, optimize the display effect of the twin model on different terminal devices, ensure that the cultural and creative twin achievements meet the dynamic application needs of metaverse digital cultural and creative design while digitally replicating the architectural culture of Haikou Qilou Old Street, and achieve cultural inheritance and design innovation.

3.Implementation of interactive experience optimization

3.1 Multimodal technology fusion

The integration of multimodal technology focuses on the deep immersion needs of cultural interaction experience in Haikou's arcade old street architecture, and builds a three-level technical architecture of "perception layer integration instruction layer adaptation feedback layer output". The perception layer integrates and focuses on collaborative applications of vision, touch, and hearing^[4].

3.1.1 visual perception

Visual perception adopts object detection algorithms in computer vision to accurately capture directional movements of users towards arcade building components (colonnade column heads, window decoration patterns, and mountain flower wall shapes). The recognition range covers the entire area of arcade buildings and key nodes of old street and alley interfaces. The algorithm optimizes recognition accuracy through pre trained arcade component feature libraries to ensure effective capture of interactive movements in low angle and obstructed scenes.

3.1.2 tactile perception

The tactile perception combined with force feedback glove device sets the feedback force curve based on the physical parameters of the arcade building material (hardness of green bricks, roughness of wood carving texture, and elasticity of gray plastic). When the user touches different components, the device simulates the tactile feedback of the corresponding material through pressure sensors.

3.1.3 auditory perception

The auditory perception is equipped with speech recognition and semantic understanding modules, which support users to trigger arcade culture queries (such as building technology, historical background), scene switching (such as from the arcade's lower commercial area to the upper residential area), and other functions through natural language commands. The semantic understanding module has a built-in arcade culture specific vocabulary library, which achieves dual adaptation of professional terminology and daily expressions.

3.2 Build experience quantification indicators

Build experience quantification indicators with Haikou Qilou Old Street architectural cultural interaction experience as the core goal (cultural transmission effectiveness, smooth interaction operation, and precise scene adaptation), and establish a "three-dimensional nine item" quantification indicator system. The cultural transmission dimension focuses on the efficiency and depth of the transmission of arcade cultural information, and sets three core indicators.

3.2.1 Recognition rate of cultural symbols

By measuring the visual recognition accuracy of arcade specific symbols (such as herringbone patterned window decorations, curved mountain flower walls, and Nanyang style column heads) during user interaction, data was collected through a combination of instant feedback questionnaires and symbol matching tests to test arcade symbol types with different levels of complexity.

3.2.2 Mastery of Cultural Content

After interaction, users evaluate the degree of memory retention of the core information of the arcade building (colonnade structure function, decoration techniques, spatial layout logic), and use structured test questions (fill in

the blank questions, true/false questions) to collect data. The question design corresponds to the cultural content presented during the interaction process.

3.2.3 Cultural and Emotional Relevance

Quantitative analysis is conducted on the cultural identity rating of interactive content by users, with sub indicators including symbol recognition, cultural restoration, and emotional resonance. Feedback information is collected using the Likert five point scale.

3.3 Adaptation and optimization of landing scenarios

Guided by the practical application scenarios of architectural culture and digital cultural creativity in Haikou Qilou Old Street, we will adapt and optimize the landing scenarios, and construct a full process implementation system of "scene classification modeling design adaptation adjustment effect verification iteration". Classify and model scenarios based on the technical environment, usage scenarios, and user demand dimensions of the application scenario. The specific core scenarios include online cultural and creative display scenarios (including digital collection platform exhibitions, virtual museum themed exhibition areas, and cultural website themed pages), with high-definition presentation of arcade building details and transmission of complete cultural information as the core requirements. User usage scenarios mainly focus on static browsing, detail viewing, and information acquisition; Offline interactive experience scenarios (including VR experience areas in physical exhibition halls, interactive terminals at old street cultural stations, and immersive installations for themed activities), with deep immersive interaction and enhanced cultural experience as the core requirements. User usage scenarios include dynamic roaming, physical operations, and multi person collaborative interaction; The core requirements for lightweight interactive scenarios on mobile devices (including WeChat mini programs, APP lightweight modules, H5 pages) are convenient access and fast experience. The user usage scenarios are mainly fragmented browsing and core function operations, which strictly limit loading speed and operation complexity^[5].

Adapt and adjust the design according to the characteristics and requirements of different scenarios, and implement precise optimization from the perspectives of content, technology, and operation. The online cultural and creative display scene focuses on the depth and breadth of content presentation, and improves the accuracy of the three-dimensional model of the arcade at the content level. It uses 8K high-definition texture mapping to restore micro features such as column corridor brick joints, wood carving patterns, and gray plastic details, and increases the layered display function of the arcade building's "structure decoration space". Users can switch between layers to view building information from different dimensions; On the technical level, optimize the model loading technology on both the web and platform ends, adopting a progressive loading strategy. After quickly presenting the low precision model, gradually load high-precision details, and support 360 degree rotation and arbitrary angle scaling of the model; At the operational level, a simple interactive control is designed, with core functions including viewpoint control, information pop ups, and collection sharing. The control style incorporates arcade window decoration elements to maintain consistency in design style.

4. Conclusion

This article studies the precise digital transformation of arcade shapes and symbols, forming cultural and creative products and interactive modes that are suitable for diverse scenarios, and providing technical support for the digital inheritance of historical architectural culture. In the future, in the process of conducting relevant research, we can further expand the dimensions of cross scenario data linkage, deepen the coupling mechanism between user behavior and cultural transmission, and promote the large-scale application of metaverse technology in the field of historical architectural cultural inheritance.

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