

Creation and Application of Cultural Digital Overlay Model: Taking Quanzhou String Puppet Show as an Example

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Abstract: The digital transformation of intangible cultural heritage (ICH) has become an important means to protect and spread traditional culture. This study constructs a cultural digital overlay model (CDOM) that integrates digital technology, design aesthetics and cultural values, and applies it in the digital display of Quanzhou traditional string puppet show. The study shows that by adopting 3D modeling, motion capture and metadata-driven design, the characteristics and performance skills of puppets are digitized, and the use of multi-sensory and mixed reality technologies enhances the audience's participation, creates an immersive interactive experience, and effectively reinterprets traditional art in a contemporary way.

Keywords: Cultural Digital Overlay Model, Intangible Cultural Heritage, Digital Display Design, Quanzhou Puppet Show, Motion Capture, Design Aesthetics, VR/AR.

1. Introduction

In the era of global digital transformation, intangible cultural heritage (ICH) faces the dual challenges of protection and dissemination. Traditional performances, crafts and oral forms of expression are at risk of being marginalized in a rapidly changing media environment. At the same time, digital technologies such as virtual reality (VR), augmented reality (AR) and artificial intelligence generation (AIGC) provide new tools for reshaping cultural content and enhancing public participation. However, current digital display design still faces many challenges in practice, mainly manifested in: too much emphasis on technical implementation, lack of in-depth exploration of cultural content and contextualized narrative; over-emphasis on visual effects, neglect of the systematic design of cultural symbols and multi-time and space superposition expression. These problems limit the effectiveness of digital display design in presenting complex cultural content, especially when it comes to the display of cultural diversity and national cultural characteristics, the dynamic dialogue and integration of cultural expression are insufficient, and the value of cultural heritage cannot be better displayed.

In this context, this study proposed and constructed the Cultural Digital Overlay Development Model (CDOM), which organically combines the three core dimensions of digital technology, design aesthetics and cultural value, uses digital technology to enhance display design, enrich cultural expression methods, enhance interactive participation, and explore innovative paths for digital display design in the display of complex cultural content. This study contributes to the interdisciplinary research of cultural heritage and provides a replicable model for future intangible cultural heritage digitization projects.

2. Literature Review

In the past two decades, the digital transformation of cultural heritage, especially intangible cultural heritage (ICH), has attracted increasing academic attention^[1]. Researchers have explored the intersection of digital technology, design

methods and heritage protection, laying the foundation for models such as the Cultural Digital Overlay Model (CDOM).

2.1. Digital Display in Cultural Heritage

Digital display design is an interdisciplinary field dedicated to using immersive and interactive media to visualize, interpret and disseminate cultural content. Ciolfi et al.^[2] emphasized that although technology has brought new opportunities to the field of cultural heritage, it has also brought theoretical and practical challenges. Especially in the museum field, augmented reality/virtual reality (AR/VR) and multimedia installations have demonstrated new models for attracting audiences to participate in heritage content. Kenderdine proposed the concept of co-evolutionary narrative environment, integrating interactive technology with historical narrative, setting a precedent for the integration of cultural narrative^[3]. Champion^[4] emphasized the importance of meaningful interaction in virtual heritage and proposed the concept of "critical games" to enhance audience reflection and historical empathy.

2.2. Models and Frameworks for the Digitization of Intangible Cultural Heritage

Despite the large number of digital heritage projects, few have been able to provide structured models that unify aesthetics, interactivity, and cultural specificity. Virtual heritage narrative structures and multisensory layered displays^[5] are early attempts to build models for digital cultural experience. However, these models often prioritize technology or narrative while neglecting holistic integration. Kenderdine's^[6] augmented panorama project and Manovich's^[7] conceptualization of media layering have influenced the development of multi-layered digital display structures. These studies suggest that we need a unified framework that integrates digital technology, design aesthetics, and cultural representation.

2.3. Gaps and Opportunities

Despite the large amount of work that has been done in the

field of digital heritage, there are still some gaps. First, existing models often lack scalability, cultural specificity, or audience-centered interactive design. Few studies have emphasized the digitization of performance-based intangible cultural heritage (e.g., puppetry) because these forms require complex metadata and motion capture strategies. Second, in the technological field, although tools such as virtual reconstruction and data visualization have been developed, the balance between authenticity and interactivity, especially in presenting sensitive cultural content, still needs to be further explored. Many reconstruction projects remain static, emphasizing visual fidelity while ignoring the multisensory and performative nature of intangible cultural heritage^[8]. Third, the symbolic and dynamic dimensions of intangible cultural heritage are often not fully explored. Most projects remain at the level of visual symbol extraction or surface cultural representation, without deeply exploring the social, historical and experiential aspects of these cultural forms.

To address these challenges, this study proposes to construct a cultural digital overlay model, which is a conceptual and practical framework that integrates design aesthetics, digital technology and cultural overlay. The model aims not only to enhance the representational depth of digital cultural heritage display, but also to provide a new methodological approach for the integration of technological tools with cultural narrative and symbolic expression.

3. Construction of CDOM Framework

3.1. Theoretical Basis

3.1.1. Digital Extension of the RMP Theory

The RMP theoretical system proposed by Professor Wu

Bihu^[9] is a classic paradigm for regional tourism development. Its core value lies in the establishment of a three-way transformation mechanism of "resources-market-product". This theoretical framework contains two basic transformation paths: one is the tourism transformation of natural geographical resources, and the other is the creative development of cultural resources. As shown in Figure 1, this analysis model achieves systematic development through three key dimensions:

The RMP theory emphasizes that in the context of increasingly fierce competition in tourism products, efforts should be made to increase the product development of cultural heritage resources and highlight the characteristics of regional cultural resources^[10]. The RMP theory believes that in the process of tourism product development, the framework model of analysis and demonstration of resources, market and product should be followed. The resource dimension (R dimension) focuses on evaluating the convertibility of regional resources, including the tourism adaptability analysis of material carriers and cultural connotations. The market dimension (M dimension) is based on the principles of consumer behavior and analyzes tourists' experience needs and selection mechanisms for cultural products. The product dimension (P) integrates the research results of the first two stages and designs cultural product forms with market competitiveness.

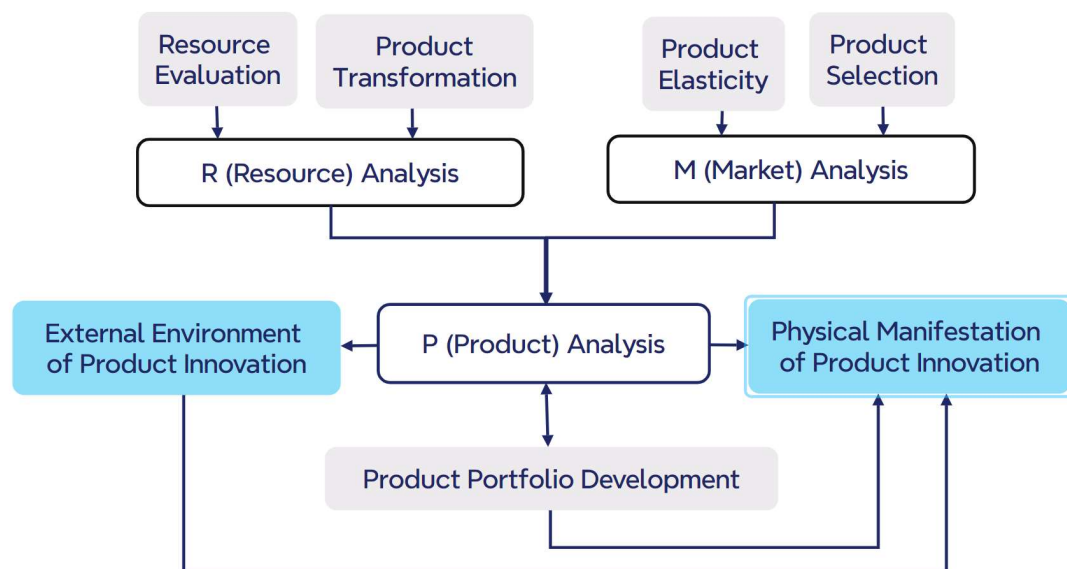


Figure 1. RMP Analysis Framework

3.1.2. Digital Expansion of the Reflection and Metaphysics (RMP) Theory

As an important cultural resource in ethnic regions, how to reasonably develop and utilize ICH, find a suitable carrier for it, and transform this "invisible, intangible, and inexperienced" ethnic traditional cultural resource into a cultural product with ethnic characteristics, and further promote the effective inheritance of ICH in development-oriented protection, requires research and design of a set of

effective innovative development models for ICH carrierization and productization. The Reflection and Metaphysics (RMP) theory takes resources, market, and product as core dimensions, and provides a systematic theoretical framework for the transformation and development of cultural resources. However, the traditional RMP theory focuses on the utilization and transformation of regional cultural resources in physical space, and does not fully involve the potential of modern digital technology and information technology in the transformation of cultural

resources. To this end, in view of the particularity of intangible cultural heritage (ICH), the traditional RMP theory needs to be further developed in the following aspects:

1) The synergistic mechanism of digital display technology and cultural resource transformation

Digital display technology effectively solves the "invisible and intangible" dissemination dilemma of intangible cultural heritage (ICH) through visualization and interactive means, and becomes a key technical path for the transformation of cultural resources into cultural products^[11]. Its core lies in the systematic extraction and digital re-creation of cultural symbols, and the explicit expression of cultural values by superimposing dynamic digital content on material carriers. To achieve this goal, it is necessary to first establish standardized data specifications: based on the category characteristics of ICH (such as performing arts, traditional crafts, etc.), build a multimodal database containing 3D models, high-fidelity audio, and structured text to ensure the compatibility of data and display technology. Secondly, it is necessary to rely on AR/VR technology to build immersive narrative scenes, such as presenting the virtual reproduction of traditional rituals through mobile terminals, and using tactile feedback to enhance user participation. This kind of technical synergy not only expands the presentation dimension of cultural resources, but also breaks the traditional one-way communication model through interactive design.

2) The logic of cultural product development based on demand elasticity

The consumption of cultural products is essentially a high-level spiritual demand, and its demand elasticity is significantly affected by digital experience preferences. Contemporary consumers, especially young people, prefer cultural products that are both entertaining, educational, and socially engaging. This feature requires developers to adopt a two-way strategy: on the demand side, cluster analysis and user profiling technology are used to accurately identify consumption behavior patterns in different scenarios^[12]; on the supply side, the expression form of ICH needs to be reconstructed, and the organic integration of knowledge transfer and entertainment experience is achieved through the design of serious game mechanisms (such as intangible cultural heritage skills level-breaking games) or AR-enhanced physical products (scanning codes to trigger cultural story animations)^[13]. It is worth noting that this development logic emphasizes the three-way interaction of "user-content-technology", and its successful implementation depends on the continuous tracking and rapid response to consumers' digital habits¹⁰.

3) The innovation paradigm of cultural products from the perspective of technological integration

Under the guidance of the CDOM framework, modern digital technology is driving the transition of cultural product innovation from physical form to "digital-physical" hybrid form^[14]. This innovation is no longer limited to carrier improvement, but rather to the reconstruction of the cultural expression system through technology empowerment: on the one hand, VR interactive devices are used to restore the spatial and temporal context of traditional festivals, allowing participants to immerse themselves in cultural scenes through motion capture technology; on the other hand, NFC chips are embedded in static handicrafts such as ethnic embroidery, and users can activate holographic demonstrations of the production process by scanning with their mobile phones^[15]. Further innovation is reflected in the diversification of

product forms, such as developing dynamic digital twins for museum artifacts, allowing viewers to explore the details of artifacts through gestures, or building a UGC platform to encourage the public to upload secondary digital content based on regional culture.

3.2. Construction of CDOM Theoretical Framework

Through the digital innovation thinking of the OP theory, the cultural digital superposition development model (CDOM) proposed in this study is a systematic integration framework based on the three dimensions of digital technology, design aesthetics and cultural value, aiming to realize the transformation of intangible cultural heritage from resource form to innovative products. This framework constructs a complete path for the development of cultural digitalization through the synergy of the three dimensions. By integrating these three dimensions, the CDOM framework realizes the full-chain transformation from cultural resources to cultural products, and promotes the protection and dissemination of intangible cultural heritage.

3.2.1. Digital Technology Dimension

In the digital technology dimension, the CDOM framework takes virtual reality (VR), augmented reality (AR) and multi-sensory interactive technology as the core support, solving the problem of "invisible and intangible" presentation of intangible cultural heritage. This dimension includes three key paths: first, establish a cultural resource database through digital modeling, systematically collect and manage multimodal data such as three-dimensional models, animations, and audio of intangible cultural heritage content, and provide a standardized data foundation for subsequent development; second, achieve the deep integration of virtual and reality, superimpose digital content on physical cultural carriers, and build a new display form that combines virtual and real; finally, establish a deep interaction mechanism between users and cultural content through the interactive design of smart terminal devices, including innovative forms such as dynamic narrative and personalized navigation. In the CDOM framework, the digital technology dimension undertakes the core functions of digital transformation of cultural resources and expansion of communication channels.

3.2.2. Design Aesthetics Dimension

In the design aesthetics dimension, the CDOM framework emphasizes enhancing the attractiveness and appeal of digital display through systematic aesthetic design. This dimension includes three progressive levels: first, the extraction and reproduction of cultural symbols, through the semiotic analysis of the core elements of intangible cultural heritage, extracting visual elements with cultural recognition; second, contextualized narrative design, placing cultural content in a specific time and space scene, and enhancing the user's sense of substitution through storytelling expression; finally, multi-sensory experience design, integrating multiple perception channels such as vision, hearing, and touch, to build an immersive cultural experience environment. This dimension plays a key role in improving user experience and emotional resonance in the CDOM framework, and is an important bridge for transforming technological applications into aesthetic expression.

3.2.3. Cultural Superposition Dimension

In the cultural superposition dimension, the CDOM framework focuses on solving the problem of modern

transformation of the value of intangible cultural heritage. This dimension achieves cultural value-added through three paths: first, the digital preservation of cultural diversity, with special attention to the systematic recording of niche and endangered cultural forms; second, the establishment of a collaborative creation mechanism for community participation, promoting interactive exchanges between cultural holders and the public through digital platforms; and finally, the innovative realization of educational functions, transforming traditional cultural knowledge into interesting digital learning products. This dimension ensures that the CDOM framework not only realizes the innovative application of technology, but also achieves the core goal of cultural inheritance, forming a virtuous cycle of technology empowerment and cultural value enhancement.

As shown in Figure 2, from the in-depth application of digital technology to the visual presentation of design aesthetics, and then to the diversified dissemination of

intangible cultural heritage values, the innovation of the CDOM theoretical framework lies in that it breaks through the one-way thinking of traditional digital protection and constructs a three-dimensional collaborative model of "technical support-aesthetic transformation-value enhancement". The digital technology dimension provides a basic means of implementation, the design aesthetics dimension completes the creative transformation of cultural content, and the cultural superposition dimension ensures the depth and sustainability of the transformation. The three dimensions support and strengthen each other, and together constitute a complete cultural digital innovation and development system. This framework is not only applicable to the protection and inheritance of intangible cultural heritage, but also provides a theoretical reference for the innovative development of cultural resources in a wider range of fields.

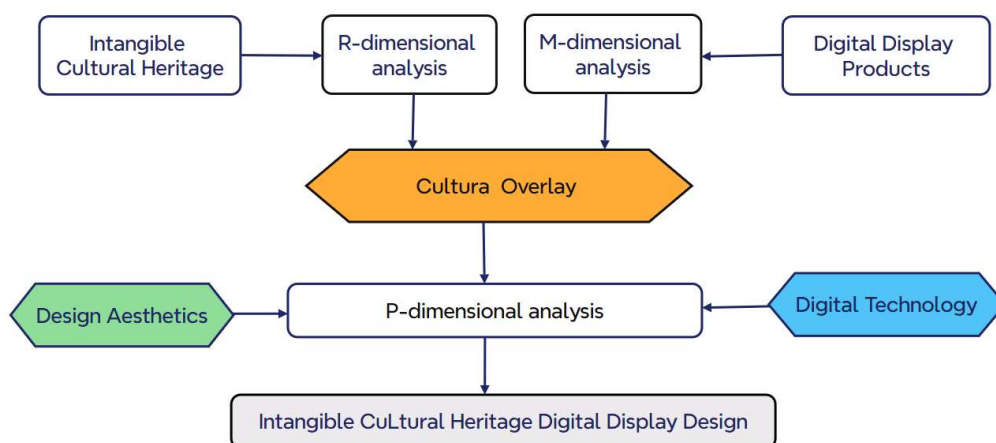


Figure 2. Framework for the Cultural Digital Overlay Model (CDOM)

4. Case Study Analysis

To verify the actual effect of the Cultural Digital Overlay Model (CDOM), this study applied it to the digital exhibition design of Quanzhou's traditional string puppet show, demonstrating how to combine digital technology, design aesthetics, and cultural values to enhance the display and inheritance of traditional cultural heritage.

4.1. Cultural Value Dimension

Quanzhou string puppet show was listed in the National Intangible Cultural Heritage List in 2006. Its rich artistic connotation integrates local history, religious beliefs, folklore, and classical opera traditions. These puppets are manipulated by more than 30 silk threads, which reflects both technical complexity and artistic expression. This section will elaborate on three aspects: historical evolution, artistic craftsmanship, and social and cultural functions.

The historical origins of Quanzhou string puppet show can be traced back to the Tang and Song dynasties, and gradually merged with local opera forms. The artistic value lies in its hand-carved puppets, traditional costumes, and stylized performance rituals. At the social level, it plays the role of a moral educator and a pillar of community culture, and is often performed during festivals and temple fairs. At the international level, puppetry is actively involved in cultural diplomacy and transnational performances, especially during

the Beijing Olympics and art festivals in France, the United States, and Southeast Asia.

4.2. Application of Digital Technology Dimension

According to the technical dimension of CDOM, the project uses 3D scanning and modeling, motion capture, VR/AR platforms, and database integration to digitize the visual and performance aspects of puppetry. High-resolution 3D laser scanning is used to digitally preserve the puppet heads and costumes, while motion capture technology records the traditional operating techniques of the masters. The data is formatted in FBX and C3D standards and integrated into a digital archive system that supports real-time visualization, distance education, and creative reuse in VR environments. In addition, we have developed a VR-based interactive system that allows users to simulate puppet manipulation through a gesture interface. The resulting immersive experience helps young users better understand the skills and narrative complexity of this traditional craft. These technologies promote dynamic restoration, performance simulation, and educational dissemination.

4.3. Design Aesthetic Dimension

In keeping with the aesthetic dimension of CDOM, the exhibition uses multimedia installations, immersive visual

environments, and narrative animations. The hybrid puppet show, titled "Legend of Little King Kong", combines live manipulation with real-time projection mapping and 3D modeling environments, enriching traditional performances with digital stage technology. Another project, "Legend of Puppetry", provides a VR puppet experience that emphasizes the accuracy of gestures and the rhythm of music. The digital animated short film "Fate Puppetry" uses narrative design to depict the intergenerational inheritance of puppetry, combining contemporary coming-of-age stories with traditional performance elements. The film received a strong educational response and promoted intergenerational dialogue on cultural preservation.

5. Discussion

The application of the Cultural Digital Overlay Model (CDOM) to the Quanzhou puppet theater demonstrates the practical effectiveness of the model in addressing the core challenges of digital presentation of intangible cultural heritage. Through the structured integration of digital technology, design aesthetics, and cultural values, CDOM provides a multidimensional approach that goes beyond the limitations of traditional presentation frameworks.

First, the case demonstrates the ability of digital technology to preserve and revitalize complex performance traditions. The combination of motion capture and 3D modeling enables detailed recording and reproduction of visual forms and dynamic movements, thereby enabling the archiving and dissemination of traditionally ephemeral performance knowledge. This echoes the suggestions of Ch'ng et al. (2020) on the role of immersive technologies in the preservation of intangible cultural heritage.

Second, the integration of design aesthetics through interactive and narrative-driven media significantly enhanced audience engagement. The use of VR narrative and hybrid visual presentation resulted in a more immersive user experience, validating earlier theoretical assertions by Manovich (2001) and Drucker (2013) on the importance of visual and narrative hierarchies in new media environments.

Finally, by highlighting cultural values, such as historical inheritance, community participation, and moral education, the project reaffirmed the potential of the Cultural Digital Overlay Model (CDOM) as a tool for preservation and recontextualization. Unlike traditional models that focus only on form or technology, CDOM enables a holistic presentation, which is consistent with UNESCO's emphasis on the protection of tangible and intangible heritage.

6. Conclusion

This study proposed and validated the Cultural Digital Overlay Model (CDOM) as an interdisciplinary framework for the digital presentation of cultural heritage. CDOM is based on contemporary digital design theory and covers three basic dimensions: digital technology, design aesthetics, and cultural values. The case study of Quanzhou puppetry shows how these dimensions can be put into practice to enhance the preservation, interpretation, and dissemination of intangible cultural heritage. The main contributions of this study include:

showing how immersive and interactive digital tools can effectively simulate traditional performance practices; proposing an aesthetic strategy to connect cultural content with user participation through narrative and mixed media; and emphasizing the importance of cultural authenticity and heritage values in digital transformation projects. The interdisciplinary nature of the CDOM model supports wider application across different heritage types, contributing to academic discussions and applied cultural practices in the digital age.

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