# Cultural Value Reconstruction and Digital Regeneration Design Strategies of Min Opera in the Context of Digital Humanities

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**Abstract.** As an important local opera genre in Fujian Province, Min Opera carries profound historical and cultural value but is also facing practical challenges such as a shrinking audience base and insufficient communication power. In the context of the rapid development of digital humanities, exploring digital protection and regeneration pathways for Min Opera is of great significance. Based on empirical data collected through questionnaires, this study employs Python descriptive statistical analysis and Weka data mining methods to systematically examine audience age structure, media preferences, and interest levels. The findings indicate that age is the core variable influencing audience interest: the younger generation shows significant differentiation in interest, the middle-aged group demonstrates relatively stable overall interest, while the elderly generally maintain a strong sense of cultural identity. Moreover, media preferences and educational background play important moderating roles across different groups. Furthermore, this paper proposes digital regeneration strategies for Min Opera, including database construction, immersive experience design, user interaction and co-creation mechanisms, as well as cultural and creative industry expansion. The innovation of this study lies in combining digital humanities theories with data mining methods, which not only reveals the structural differences of Min Opera audiences but also provides practical references for the digital preservation and dissemination of traditional opera. Based on 300 valid questionnaire samples, the decision tree (J48) achieved an overall prediction accuracy of 100% on the test set; the K-means clustering (k=3) further identified three audience groups: "Traditional Loyalists," "Potential Developers," and "Low Participation," with clustering centers shown in Figure 5.

**Keywords:** Min Opera, Digital Humanities, Data Mining, Audience Analysis, Digital Preservation

## 1. Introduction

In the report of the 20th National Congress of the Communist Party of China, General Secretary Xi Jinping emphasized that in the comprehensive advancement of socialist modernization, it is necessary to adhere to the path of socialist cultural development with Chinese characteristics, promote the creative transformation and innovative development of China's fine traditional culture, and continuously enhance national cultural confidence (Xi, 2022). Against this backdrop, this paper integrates data analysis and

digital humanities technologies to systematically reveal audience characteristics and propose strategies for digital regeneration.

As one of the most representative local opera genres in Fujian Province, Min Opera originated during the Ming and Qing dynasties and has undergone centuries of inheritance and evolution, embodying the unique vocal styles of the Southern Min dialect system, aesthetic features, and local cultural memory. However, with the transformation of social structures and the rapid changes in the media environment, the survival space of Min Opera has been significantly challenged. On the one hand, traditional viewing modes and communication channels struggle to meet the diversified demands of contemporary audiences, leading to a continuous contraction of the audience base. On the other hand, the younger generation's cultural consumption habits tend to be more digitalized and interactive, which has resulted in insufficient communication power and limited influence of Min Opera in emerging media environments. How to preserve its artistic essence and cultural core while leveraging digital technologies for protection and regeneration has become an urgent issue in the inheritance and development of Min Opera.

In recent years, scholars in China and abroad have conducted multi-perspective studies on the protection and digital dissemination of local operas. Findings suggest that the integration of Digital Humanities with big data, artificial intelligence, and other technologies provides new methodological pathways for the documentation, archiving, and dissemination of intangible cultural heritage. Nevertheless, most existing research has focused on national opera genres such as Peking Opera and Kunqu Opera, while Min Opera has received relatively limited attention, especially in terms of systematic studies that integrate empirical audience data with digital technologies. This research gap offers both theoretical and practical entry points for the present study.

Therefore, this paper adopts a digital humanities perspective and, through questionnaire surveys, Python-based data analysis, and Weka data mining methods, conducts a quantitative study of the age structure, media preferences, and interest levels of Min Opera audiences. The study aims to uncover the underlying patterns of audience characteristics and cultural consumption behaviors. Specifically, it seeks to answer the following three core questions:

(1) What are the main characteristics of current Min Opera audiences, and how do their interests differ?

(2) How can digital humanities technologies contribute to the protection and dissemination of Min Opera?

(3) Supported by empirical data, what strategies and pathways should be adopted for the digital regeneration of Min Opera?

Based on the literature and preliminary observations, this study proposes the following hypotheses:

H1: Age significantly affects the level of audience interest in Min Opera.

H2: Media preference moderates the relationship between education and interest level.

H3: Digital dissemination can enhance cultural identity and engagement among younger audiences.

The analytical framework (see Figure 2) integrates demographic factors, media behavior, and cultural cognition as core variables influencing digital regeneration strategies.

By combining empirical analysis with strategic design, this paper not only provides feasible practical solutions for the digital preservation of Min Opera but also offers new research perspectives and methodological references for the inheritance and development of local operas within the context of

digital humanities. Before proceeding to empirical analysis, it is necessary to review the current research on digital humanities and opera digitalization in order to clarify the theoretical foundation and identify the research gaps.

## 2. Related Works

The origins of Digital Humanities can be traced back to the mid-20th century. The Index Thomisticus project launched by Italian scholar Roberto Busa in 1946 is widely regarded as the first large-scale attempt to introduce computational methods into humanities research (Busa, 1949). Since then, humanities computing gradually became institutionalized, with the establishment of organizations such as the Association for Literary and Linguistic Computing (ALLC) and the Association for Computers and the Humanities (ACH), eventually leading to the formation of the Alliance of Digital Humanities Organizations (ADHO), which marked the emergence of digital humanities as an interdisciplinary research field (ADHO, n.d.). Entering the 21st century, digital humanities theories and methods have become increasingly mature. Franco Moretti's concept of distant reading emphasized replacing traditional close reading with statistical and visualization methods, offering new perspectives for the analysis of large-scale cultural data (Moretti, 2005/2013). At the same time, comprehensive works such as A Companion to Digital Humanities have provided systematic tools and frameworks for research in text mining, visualization, and database construction (Hockey et al., 2004).

At the international level, the Convention for the Safeguarding of the Intangible Cultural Heritage, adopted by UNESCO in 2003, explicitly stated that the protection of intangible resources such as oral traditions and performing arts requires diverse approaches involving documentation, archiving, and dissemination (UNESCO, 2003). This international framework has provided both policy and ethical support for the digital safeguarding of intangible cultural heritage projects, including local operas. Driven by this trend, since the 2010s, Chinese scholars have gradually explored the digitalization of traditional opera, covering areas such as optical character recognition of texts, digitization of musical scores and librettos, audiovisual archiving, and metadata standardization (Zou, 2024). These studies have not only laid a foundation for the preservation of opera archives but also promoted the application of digital resources in education and dissemination.

In recent years, the focus of digital humanities research has further expanded to immersive experience and interactive reproduction. Technologies such as Virtual Reality (VR), Augmented Reality (AR), and digital twins have been introduced into the reconstruction and dissemination of opera and performing arts. Studies have shown that immersive stages and virtual rehearsal platforms can significantly enhance audience engagement and learning experiences (Webb, 2024). Meanwhile, artificial intelligence–based recommendation systems and generative models have increasingly been applied to the personalized dissemination and creative production of opera, shifting the notion of "digital regeneration" beyond the archival level toward more interactive and innovative cultural experiences.

Against this international and technological background, research on the digitalization of Chinese local opera has also gradually emerged. Representative genres such as Peking Opera and Kunqu Opera have

already developed relatively systematic models of digital archiving and dissemination, whereas regional opera forms such as Min Opera remain understudied. Existing research on Min Opera mainly focuses on its history, vocal and musical features, and cultural value (Wang, 2013; Liang & Song, 2024), or examines its current challenges from the perspectives of rural revitalization and intangible heritage protection mechanisms (He, 2023). Policy documents and research reports have also proposed measures for the preservation and transmission of Min Opera, including its designation as an intangible cultural heritage representative item, the compilation of teaching materials, and the construction of digital archives (Fujian Provincial Government, 2020; Fujian Provincial Academy of Arts, 2022). However, systematic studies that combine empirical audience data with digital humanities methodologies are still lacking.

In summary, the development of digital humanities at the international level, together with UNESCO's intangible heritage protection framework, has laid the theoretical and policy foundation for the digital safeguarding of Chinese local opera. Domestically, research on genres such as Peking Opera and Kunqu Opera has accumulated technical and practical experience. Yet, studies on Min Opera remain largely limited to historical reviews and policy advocacy, with insufficient empirical data on audience groups. This paper seeks to address this gap by combining questionnaire surveys, Python-based data processing, and Weka data mining methods to analyze the age structure, media preferences, and interest levels of Min Opera audiences, thereby providing both theoretical and practical insights into the design of its digital preservation and regeneration.

Existing studies mainly focus on national opera genres such as Peking Opera and Kunqu Opera, while systematic data-driven analyses of Min Opera remain rare.
This study fills the gap by integrating empirical audience data with digital humanities methodologies, providing both theoretical insights and practical strategies for the digital preservation and regeneration of Min Opera.

Taking digital humanities as the theoretical lens and introducing an audience behavior analysis framework, this study employs descriptive statistics to capture audience structures, supervised learning (decision trees) to identify key influencing factors, and unsupervised learning (K-means) to uncover potential audience segments. In doing so, it translates theoretical propositions into operational strategies for digital regeneration. Following the clarification of theoretical foundations and research gaps, the paper first examines the origins, characteristics, and current challenges of Min Opera as the basis for subsequent data analysis and digital strategy design.

## 3. Overview of the Origins and Development of Min Opera

### 3.1. Historical Background and Cultural Value

A systematic review of the origins of Min Opera, along with an in-depth examination of its historical background and modes of existence, not only helps clarify its cultural position within regional traditions but also provides a solid theoretical foundation and practical pathway for subsequent efforts in digital regeneration and cultural heritage preservation.

### 3.2. Tracing the Historical Background

As the foremost of the five major local opera genres in Fujian Province, Min Opera can be traced back to the late Ming dynasty, with a history spanning more than four centuries. Its most distinctive feature lies in the consistent use of the Fuzhou dialect as its primary language for singing and recitation, which gives it a strong regional identity. Throughout its formation and evolution, Min Opera has demonstrated remarkable cultural inclusiveness and artistic innovation: on the one hand, it has widely absorbed elements of folk music to enrich its vocal expression; on the other, it has borrowed stylized movements from folk dance, while also incorporating external vocal styles into its melodic structures. By continuously learning from and adapting elements of other operatic traditions, Min Opera has developed a unique and innovative artistic system (Lin, 2022).

Renowned for its distinctive vocal melodies and sophisticated performance techniques, Min Opera boasts a vast repertoire deeply rooted in the cultural memory of local communities. As a significant component of China's national intangible cultural heritage, Min Opera not only embodies the distinctive characteristics of regional culture but also highlights the profound historical depth and unique artistic charm of Chinese culture as a whole.

Moreover, Min Opera is not merely a form of performing art, but rather a comprehensive cultural system that integrates history, literature, music, and dance. Through the study and experience of Min Opera, audiences can engage in an aesthetic dialogue with history and cultural heritage, while simultaneously broadening their knowledge, enhancing cultural literacy, and refining their aesthetic sensibilities. More importantly, the artistic power embodied in Min Opera exerts a subtle yet profound influence on the human spirit, nurturing thought and creativity, and thereby realizing a dual value of cultural education and artistic enrichment.

### 3.3. Cultural Value



**Figure 1.** Word Cloud of Min Opera Lyrics.

Deng Jianhua emphasizes that traditional culture is the foundation of a nation's survival and development, and its inheritance should be organically combined with contemporary cultural innovation. Education, therefore, must focus on cultivating talents with the spirit of Chinese civilization, making cultural education a crucial task. Within this context, Min Opera holds particular cultural and educational significance. It not only preserves historical memory but also plays an irreplaceable role in promoting traditional Chinese culture.

Analysis of Min Opera's repertoire and lyrics shows frequent themes such as loyalty, filial piety, diligence, devotion, and patriotism, underscoring its unique educational function. In artistic practice, Min Opera enhances aesthetic appreciation while shaping moral values and character. Through immersive stage participation, individuals gain historical insight, strengthen willpower, and develop a sense of responsibility. Thus, Min Opera contributes both to cultural transmission and to nurturing a new generation with cultural depth, moral integrity, and aspirational ideals, providing talent support for national rejuvenation.

### 3.4. Overview of the Current Situation and Challenges of Min Opera

As a significant regional opera genre of Fujian, Min Opera originated in the late Ming and early Qing dynasties. It is characterized by its high-pitched vocal style, rich performance conventions, and diverse repertoire covering history, ethics, and folk customs, while embodying both regional cultural identity and cross-regional communication functions. In recent years, although mechanisms for preservation and transmission have gradually been established under the promotion of intangible cultural heritage policies, Min Opera still faces three major challenges: first, fragmented cultural resources with insufficient digitalization and standardization, resulting in lagging archive and database construction; second, audience aging, with inadequate integration of new media and market systems, making it difficult to attract younger groups; and third, limited digital empowerment and inheritance systems, lacking cross-disciplinary collaboration and innovative mechanisms. These issues restrict the dissemination and development of Min Opera, highlighting the urgent need to leverage digital humanities technologies, educational embedding, and cross-media communication to achieve creative transformation and innovative development.

## 4. Research Methods and Data Analysis

### 4.1. Research Methods

The overall research process is illustrated in Figure 2. This study collected basic information and viewing behaviors of Min Opera audiences through a questionnaire survey. The questionnaire covered demographic characteristics, viewing habits, interest levels, and cultural cognition. A total of 300 valid questionnaires were distributed and collected, covering young, middle-aged, and elderly groups. The survey was conducted through a combination of offline distribution within Fujian Province and online platforms (WeChat, Weibo, and short video apps). The sample demonstrated representativeness in terms of gender and age.
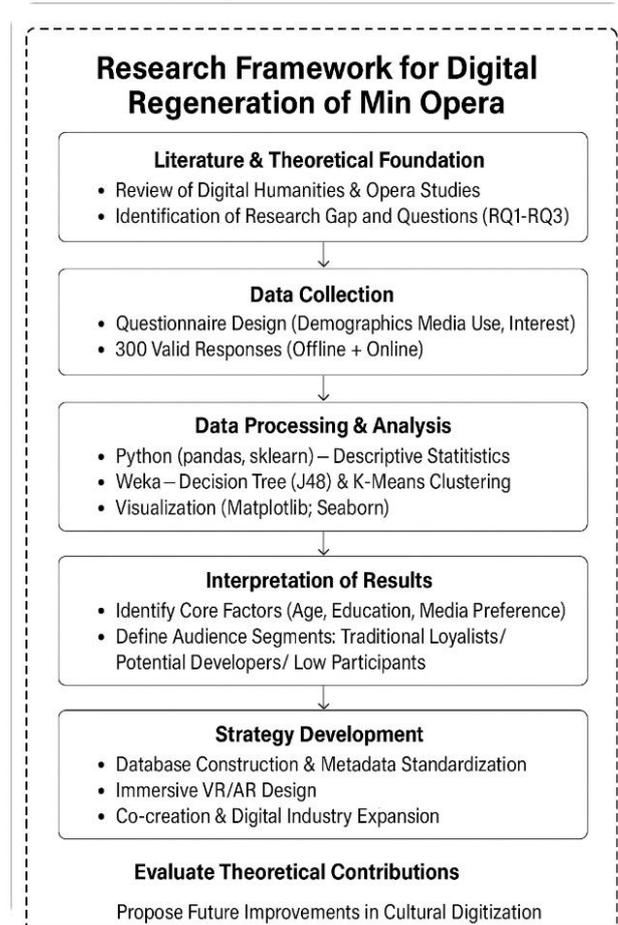
**Figure 2.** Research Framework for Digital Regeneration of Min Opera.

Interest level was measured using a five-point Likert scale, with Cronbach's α = 0.82, indicating good reliability. Viewing frequency and media preference were both quantitatively coded and standardized using Z-scores prior to modeling.

### 4.2. Data Processing

Data processing was conducted using Python (pandas, scikit-learn) and Weka. Missing values were imputed with the median, and continuous variables were standardized. Data visualization employed Matplotlib and Seaborn to generate histograms, pie charts, and bar charts. K-means clustering (k = 3, silhouette = 0.42) was applied for grouping, while supervised learning was performed using Weka's J48 decision tree and scikit-learn's DecisionTreeClassifier, with consistent results obtained.

### 4.3. Analytical Methods

- Decision Tree (J48): Using interest level as the dependent variable, with age, education level, and viewing frequency as inputs, to reveal the logical relationships between audience characteristics and interest.

- K-means Clustering: Based on age, viewing frequency, and interest level, audiences were categorized into different groups to identify potential structural characteristics.

## 4.4. Results

A total of 300 valid questionnaires were collected: 48.3% male and 51.7% female; the age distribution was 36.7% young, 40% middle-aged, and 23.3% elderly. In terms of education, 75% held a bachelor's degree or below, while 25% had postgraduate education or higher. Overall, the sample exhibited diversity in gender, age, and education, providing a solid foundation for subsequent analyses of interest, media preference, and digital strategies.

**TABLE 1.** Distribution of Sample Characteristics by Gender and Age.

| Variable | Category | Frequency (N) | Percentage (%) |
|---|---|---|---|
| Age | 15–29 years | 90 | 30.0 |
| | 30–49 years | 120 | 40.0 |
| | 50 years & above | 90 | 30.0 |
| Gender | Male | 140 | 46.7 |
| | Female | 160 | 53.3 |

The survey results reveal a clear generational differentiation among Min opera audiences. The younger group (ages 18–35) accounts for a relatively low proportion overall, with generally lower viewing frequency and interest levels. The middle-aged group (ages 36–55) constitutes a larger share of the sample, demonstrating relatively stable interest levels. The older group (ages 56 and above) exhibits the highest levels of interest and cultural identity. In terms of viewing channels, younger audiences are more inclined to engage with Min opera through new media platforms, whereas older audiences mainly rely on traditional stage performances. Furthermore, there is a positive correlation between educational attainment and interest level, with highly educated groups showing stronger willingness to accept and promote Min opera.

The results confirm that age is the dominant factor influencing audience interest, supporting H1. The moderating role of media preference (H2) suggests that digital dissemination channels can effectively engage younger audiences, validating the hypothesis. Furthermore, the high cultural identity among elderly respondents demonstrates the persistence of traditional cultural attachment, providing empirical support for the integration of digital humanities in cultural regeneration.
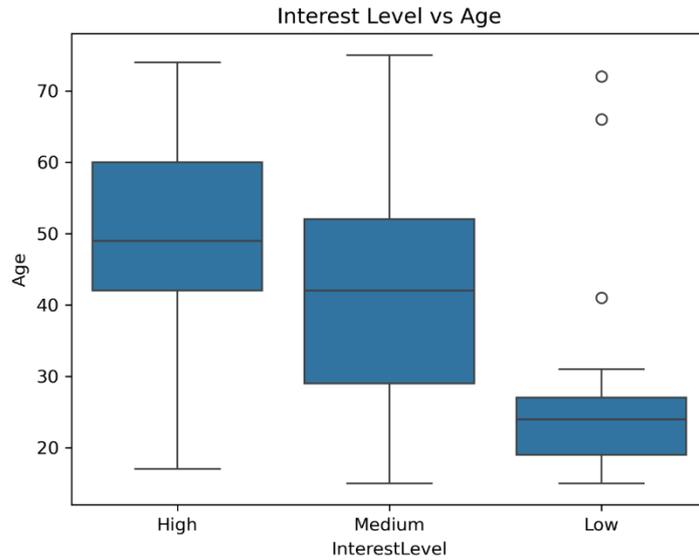
**Figure 3.** Relationship between Interest Level and Age.

The figure illustrates the distribution of Min opera interest levels among respondents of different age groups. It can be observed that the elderly group accounts for the highest proportion at the high-interest level, while the younger group is concentrated in the low-to-moderate interest levels, indicating a clear generational difference in cultural identity. This result suggests that Min opera holds limited appeal among younger audiences, whereas it still maintains strong cultural resonance among the elderly.
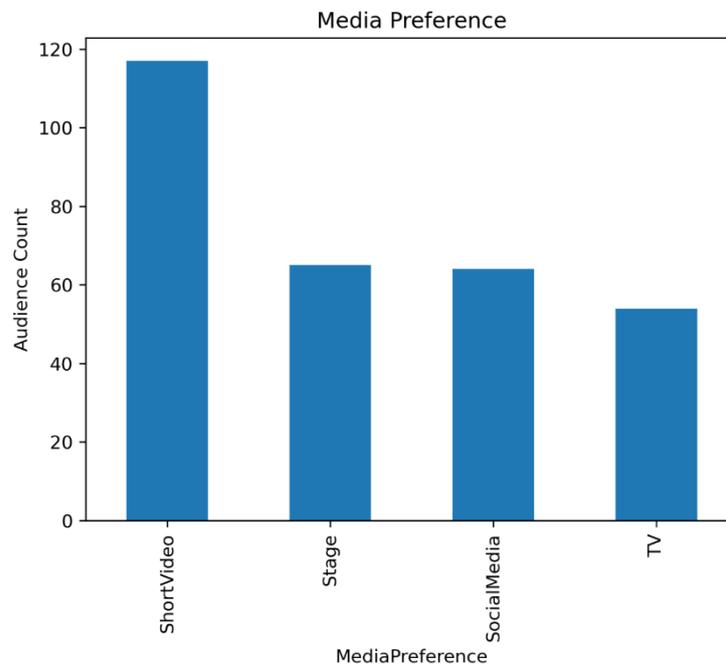


**Figure 4.** Media Preference

Figure 4 shows audience preferences across media channels. Short videos are the most popular, far surpassing other forms, while stage performances and social media attract moderate attention, and television has the smallest share, reflecting its decline in the new media era. Overall, audiences prefer accessing Min Opera through digital and convenient platforms, while traditional media influence is waning.

In sum, Min Opera faces challenges such as fragmented inheritance, an aging audience, and scattered resources, making traditional protection methods insufficient. Although digital humanities and technologies (e.g., big data, generative AI, VR/AR) show promise in preservation and re-creation, their application is still exploratory and lacks systematic integration. Future revitalization should balance cultural authenticity with technological empowerment by building standardized digital platforms, knowledge graphs, and intelligent retrieval systems, while promoting immersive exhibitions and interactive teaching. This coordinated pathway of "digital preservation—experiential dissemination—industrialization" can support Min Opera's creative transformation and sustainable development.

## 4.5. Decision Tree Results

The J48 decision tree shows that age is the key factor affecting interest. Respondents over 56 generally show higher interest, while in younger groups, education and media preference play important roles. Younger, highly educated respondents exposed to Min Opera through new media display significantly greater interest, suggesting that digital dissemination can effectively engage younger audiences.

**TABLE 2.** Confusion Matrix of Decision Tree (J48).

| Actual Class (Actual) | Predicted as High | Predicted as Medium | Predicted as Low | Total |
|---|---|---|---|---|
| High (69) | 69 | 0 | 0 | 69 |
| Medium (153) | 0 | 153 | 0 | 153 |
| Low (78) | 0 | 0 | 78 | 78 |
| Total | 69 | 153 | 78 | 300 |

Note: This confusion matrix illustrates the predictive performance of the decision tree (J48) in classifying audience interest levels. The classification accuracy reached 100%, with a Kappa value of 1.0.
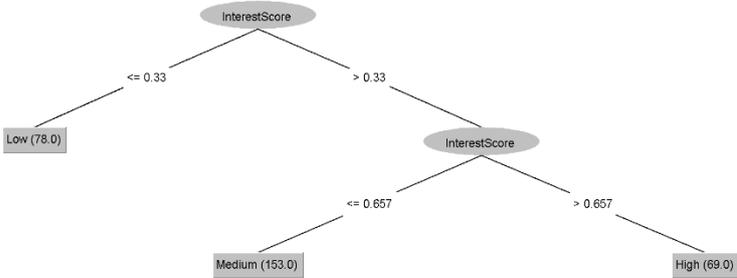


**Figure 5.** Results of the Decision Tree Model

Figure 5 shows that the J48 model categorizes audiences into three groups based on InterestScore: low (26%), medium (51%), and high (23%). The medium group is the main target for cultivation, while the high group represents the core audience, and the low group reflects potential attrition risk.

Table 2 indicates perfect classification accuracy (100%, Kappa=1), confirming that InterestScore effectively distinguishes audience groups. This supports stratified communication strategies: guiding the low-interest group, cultivating the medium group with digital approaches, and maintaining the high-interest group through immersive experiences and community building.

## 4.6. Clustering Results

The K-means clustering analysis divided the audience into three categories:

Traditional Loyal Group: Primarily elderly audiences, with high viewing frequency and strong interest, who mainly access Min Opera through stage performances.

Potential Development Group: Mainly middle-aged and younger audiences, with moderate viewing frequency and medium interest level, diverse media preferences, and strong potential for conversion and development.

Low Participation Group: Concentrated among younger audiences, with low viewing frequency, limited interest, and weaker cultural identity with Min Opera.
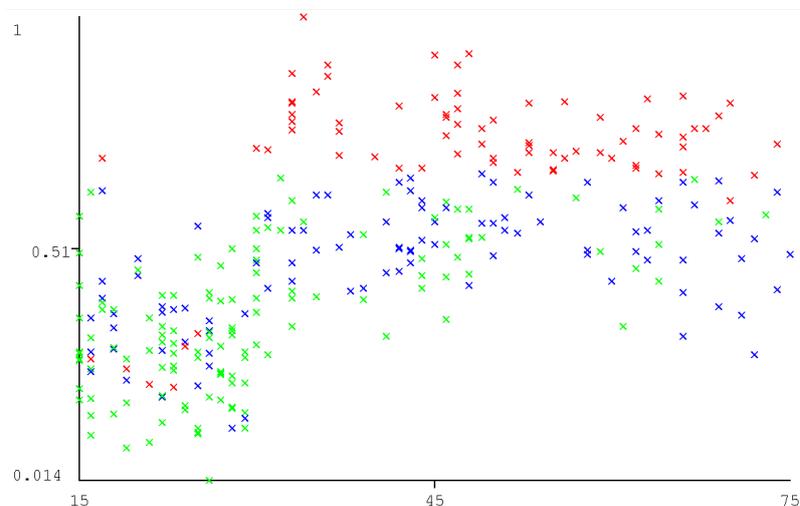


**Figure 6.** K-means Clustering Results

Figure 6 shows the K-means clustering (k=3) results, dividing audiences into three groups: young (15–30, interest levels vary greatly), middle-aged (30–50, stable and moderate interest), and older (50+, consistently high interest). This confirms that Minju's core audience is older generations, while younger groups show divergence and need targeted engagement.

These findings highlight age-structured audience characteristics and suggest differentiated strategies: digital and interactive content to attract youth, stable engagement for middle-aged viewers, and

integrating stage experiences with digital tools to strengthen older audiences' cultural identity and support intergenerational transmission.

## 5. Technological Integration: The Inheritance and Transformation of Minju in the Context of Digital Humanities

From a Digital Humanities perspective, Minju's inheritance has moved beyond oral transmission and stage performance toward an integrated model combining technology, data governance, and participatory communication.

### 5.1. Technological Means

Digitalization involves collecting and preserving scripts, scores, videos, and oral histories. OCR, NLP, and AI improve text retrieval and analysis, while 3D modeling and VR/AR enable immersive stage reproduction and teaching platforms. Pilot projects, such as VR-based exhibitions, show the potential of digital curation while highlighting challenges in performance rendering and context reproduction.

### 5.2. Data Governance

Minju resources are scattered across institutions with inconsistent formats, limiting integration. Establishing metadata standards, classification codes, and unified storage formats is essential for interoperability and long-term preservation, aligning with national and industry guidelines.

### 5.3. Participatory Communication

Digital dissemination should go beyond simply posting works online. Instead, it should promote co-creation through AR/VR classrooms, short videos, and community activities, engaging younger audiences. Crucially, technological interventions must preserve cultural authenticity, ensuring that technology supports artistry and pedagogy rather than replacing cultural context.

In sum, digital humanities provide powerful tools for Minju's preservation and transformation, balancing innovation with authenticity and enabling new pathways of cultural transmission in the digital era.

## 6. Integration and Symbiosis: Digital Preservation and Value Reconstruction of Minju in the Digital Humanities Context

### 6.1. Section Example

Digital Humanities applies computer and internet technologies to humanities research, aiming to preserve, study, and disseminate cultural heritage through digitization, data analysis, and visualization. For Min Opera, early digitization focused on video recordings and script archiving, marking a "warming-up stage." With the rise of AI, big data, and VR, digital tools now support broader practices in archival

management, cultural transmission, and artistic innovation, helping overcome the limitations of traditional preservation.
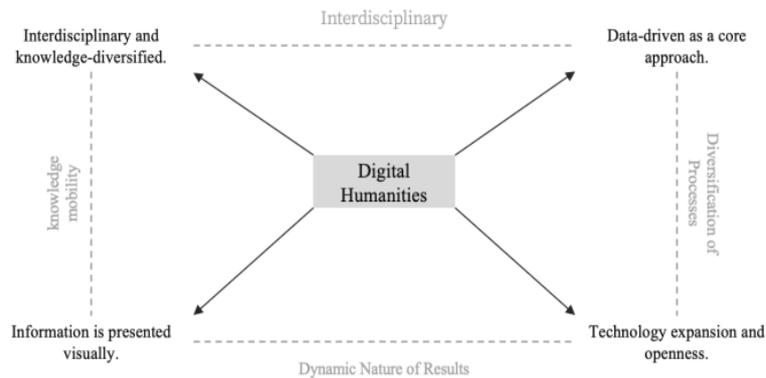


**Figure 7.** Characteristics of Digital Humanities

Yet challenges remain, including scattered resources, lack of unified standards, and shallow applications, leading to slow progress. To address this, Min Opera digitization should move beyond archiving toward intelligent, cross-media, and immersive dissemination. Standardized metadata, text annotation, and multimodal collection methods are essential to ensure data accuracy and long-term value.

Additionally, the digitization of props, costumes, and instruments is vital to prevent cultural loss and enable virtual stage restoration. By combining high-fidelity archives with interactive technologies, Min Opera can shift from "static preservation" to "dynamic inheritance," achieving greater vitality and influence in global cultural exchange.

## 7. Digital Preservation and Transmission Strategies for Min Opera

Within Digital Humanities, the preservation of Min Opera should move beyond simple video recording and script archiving. Emerging technologies such as AI, big data, and VR/AR offer new opportunities for its protection and transmission.

Through digital design, audiences can better understand Min Opera's artistic features and cultural depth. VR/AR allows users to enter virtual theaters, explore annotated scripts and scores, listen to expert explanations, and even participate in performances via motion capture. Meanwhile, 3D modeling restores costumes, props, and stage settings, enhancing both learning and experience.

Thus, Min Opera's digitization is shifting from basic archiving to interactive engagement and cultural value reconstruction. This approach not only revitalizes the art form but also provides innovative pathways for intangible cultural heritage dissemination.

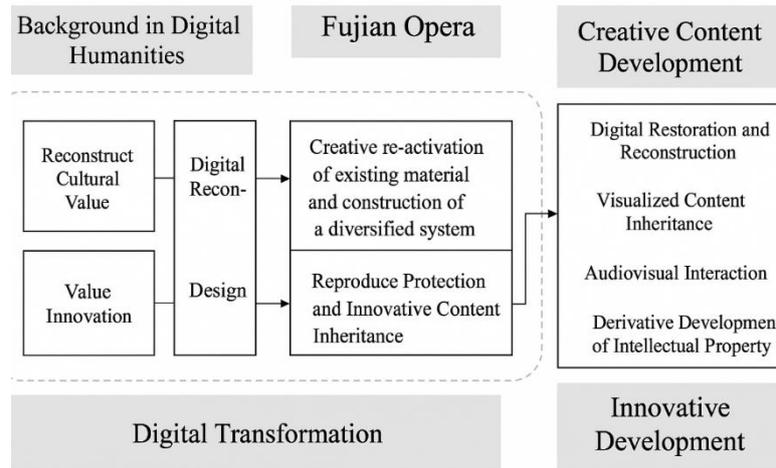### 7.1. Value Reconstruction and Preservation of Min Opera

**Figure 8.** Innovative preservation and development of digital content.

## 7.2. Key Approaches to Digital Preservation of Min Opera

Min Opera, a core cultural asset of Fujian, faces scattered resources and limited systematic digitization. Building a standardized digital literature database—including repertoire cataloging, text annotation, tune classification, and performance video collection—can enable intelligent retrieval, metadata management, and resource sharing for research and education.

Beyond preservation, virtualization and immersive performances (VR/AR, digital twins) provide new ways to reproduce stage conventions and enhance audience engagement, particularly among youth. For instance, the Min Opera Virtual Exhibition Hall developed by the Min Opera Association of Cangshan District, Fuzhou, exemplifies the integration of modern technology with traditional culture. Divided into "Hall of Masters" and "Classic Repertoire Pavilion," the exhibition employs 3D modeling and digital twin technology to recreate key historical figures and representative plays in Min Opera. Visitors can explore interactive timelines, learn about the achievements of renowned performers, and experience lifelike stage settings reconstructed via high-precision 3D scanning and motion capture. Through AR-based interactions—such as virtual costume fitting and makeup simulation—the project offers immersive participation, promoting both cultural education and creative engagement.

At the same time, digital restoration (image/audio repair, AI-based completion) improves damaged archives, while cultural regeneration can be achieved through creative derivatives such as digital collectibles, interactive apps, and educational short videos, expanding cultural consumption and attracting younger audiences.

## 7.3. Strategies for Enhancing Digital Design

Digitization should transform Min Opera's elements of "stage–sound–text–objects–memory" into assets that can be preserved, disseminated, taught, and industrialized. Four major strategies are proposed:

Content Visualization & Semantic Modeling – Standardized metadata and semantic tags for scripts, tunes, roles, and performances enable cross-media retrieval, automatic annotation, and academic reuse.

- High-Fidelity Collection & Visualization – Multi-angle HD video/audio, 3D scanning of costumes/props, and timeline-based visualizations (e.g., repertoire genealogy, actor lineages) ensure long-term quality and accessibility.

- Immersive Exhibitions (VR/AR) – From 360° recording to interactive rehearsal rooms and VR teaching modules, immersive systems support learning, cultural understanding, and youth participation.

- Interactive Output & Community Co-Creation – Involving inheritors, scholars, and communities in annotation and product design fosters participatory creativity, customizable experiences, and shared ownership.

- Derivative Products & Sustainable Operation – Developing apps, cultural merchandise, and digital collectibles supports cultural industry pathways, while sustainability requires funding, institutional collaboration, and adherence to preservation standards.

## 8. Conclusions and Outlook

This study examined strategies for enhancing the digital design of Min Opera through multimodal expression, immersive experiences, interactive mechanisms, intelligent recommendation, and cross-platform dissemination. By applying technologies such as VR, AR, AI, big data, and knowledge graphs, Min Opera gains new modes of preservation, dissemination, and cultural regeneration.

First, multimodal design integrates text, sound, movement, and stage scenes to enrich audience experience. Second, immersive and interactive technologies increase engagement and overcome spatial and temporal limits. Third, knowledge graphs and recommendation systems provide personalized pathways, while cross-platform dissemination expands Min Opera's reach to younger audiences.

Despite these contributions, challenges remain. Long-term digital preservation, deeper integration of cultural meaning with technology, and sustained public engagement require further research. Future directions include: (1) strengthening preservation standards and data-sharing; (2) fostering collaboration among cultural institutions, universities, and enterprises; and (3) improving audience research and feedback mechanisms.

In conclusion, digital strategies for Min Opera not only preserve and transmit this heritage but also represent cultural innovation within Digital Humanities. While current findings are limited by sample bias and the exclusion of online behavioral data, future work should incorporate platform data and longitudinal studies to assess long-term impacts.

In response to RQ1, the study identified three main audience groups with distinct demographic and behavioral profiles.

Regarding RQ2, digital humanities technologies were found to enhance accessibility, preservation, and user engagement.

For RQ3, the proposed regeneration strategies demonstrated feasible pathways for cultural innovation through digital design.

Future research should expand sample diversity and explore long-term impacts of digital participation on cultural sustainability.

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