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ORIGINAL

An examination of how digital media art is used in Chinese opera stage designs

Un examen de cómo se utiliza el arte de medios digitales en los diseños escénicos de la ópera china

Zhiyong Yang[1]

[1]School of Language and Culture, Graduate University of Mongolia, Ulaanbaatar City. Mongolia.

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ABSTRACT

Introduction: this study examines the use of digital media art in Chinese opera stage design and its impact on audience experience and opera expression. By introducing digital technologies such as virtual reality, holographic projection, and lighting design, this paper aims to enhance the visual expressiveness of the opera stage, optimize resource allocation, and increase the audience's sense of immersion.
Methods: a series of experiments were designed to assess the role of digital media technologies in stage resource utilization, the impact of color palette on emotional expression, and the audience's sense of immersion and emotional resonance.
Results: the experimental results show that digital media technology significantly improves the stage's visual effect, increases resource utilization rate by 20 %, and significantly enhances the audience's immersion and emotional resonance index.
Conclusion: optimizing stage resource allocation through digital means not only reduces energy consumption but also improves performance efficiency. The study concludes that digital media art provides an innovative path for the modernization and digital development of Chinese opera and is expected to play an important role in the future dissemination and innovation of opera culture.

Keywords: Digital Media Art; Opera Stage Art Design; Virtual Reality; Holographic Projection; Immersion; Resource Optimization.

RESUMEN

Introducción: este estudio examina el uso del arte de medios digitales en el diseño escénico de la ópera china y cómo influye en la experiencia del público y en la expresión operística. Al introducir tecnologías digitales como la realidad virtual, la proyección holográfica y el diseño de iluminación, se busca mejorar la expresividad visual del escenario de ópera, la asignación óptima de recursos y la sensación de inmersión del público.
Métodos: se diseñaron una serie de experimentos para evaluar el papel de las tecnologías de medios digitales en la utilización de recursos escénicos, el impacto de la paleta de colores en la expresión emocional y la percepción de inmersión y resonancia emocional en el público.
Resultados: los resultados experimentales muestran que la tecnología de medios digitales mejora significativamente el efecto visual del escenario, aumenta la tasa de utilización de recursos en un 20 % y mejora significativamente el índice de inmersión y resonancia emocional del público.
Conclusión: optimizar la asignación de recursos escénicos mediante medios digitales no solo reduce el consumo de energía, sino que también mejora la eficiencia del rendimiento. El estudio concluye que el arte de medios digitales proporciona un camino innovador para la modernización y el desarrollo digital de la ópera china y se espera que desempeñe un papel importante en la difusión y la innovación de la cultura operística en el futuro.

Palabras clave: Digital Media Art; Opera Stage Art Design; Virtual Reality; Holographic Projection; Immersion; Resource Optimization.

INTRODUCTION

Chinese opera, a significant component of traditional Chinese culture, has been passed down through the ages and evolved into a distinctive art form that incorporates acting, singing, reading, performing arts, and stage design.[1] However, with the rapid development of modern information technology and the arrival of the digital media era, traditional opera is facing challenges such as a single mode of communication and declining attractiveness in front of contemporary audiences. In order to adapt to the needs of the times and protect and inherit the culture of opera, stage art design must be innovative and transformed to give opera art a new vitality based on rich digital media technology.[2] In order to give a theoretical and practical foundation for the modernization and innovation of Chinese opera, this paper will address the application of digital media art in stage art design.

The stage art design of Chinese opera has always emphasized the combination of reality and imagination, conveying the unique aesthetic imagery of opera through simple sets and imaginative stage space.[3] In the performance of traditional opera, the role of stage art is not only to provide visual support for the drama, but also to convey the connotation of the plot, to create an emotional atmosphere, and even to guide the audience's imagination.[4] However, the traditional stage design is mostly limited by technical conditions, and the expression method is relatively single, which cannot fully meet the increasing aesthetic demand of modern audiences.

Opera stage art design has a new avenue for growth as a result of the advancement of digital media technology, particularly the maturity of holographic projection, 3D modeling, virtual reality (VR), augmented reality (AR), etc.[5] Digital media technology has a high degree of flexibility and creativity, which not only expands the expression of stage space, but also enhances the audience's sense of immersion and participation, forming a deep fusion of traditional opera and modern technology.[6] This integration not only provides more possibilities for the stage presentation of opera art, but also promotes the innovative development of opera in contemporary cultural communication.

Although the application of digital media art has brought new development opportunities for Chinese opera stage design, its promotion and application still face many challenges. The first is the contradiction between tradition and modernity. As an art form with deep historical and cultural connotations, the performance of opera has a strict program and aesthetic norms, how to retain the traditional aesthetic essence of opera on the basis of reasonable integration of modern digital technology to avoid cultural alienation brought about by over-modernization is an important issue.[7]

Secondly, the application of digital media technology requires high cost and complex equipment support, how to realize efficient artistic design under limited resources, and ensure the integrity of the stage design effect, is a realistic problem faced by stage designers.[8] Furthermore, the use of digital technology also requires stage designers to have interdisciplinary knowledge and skills, not only to be familiar with the artistic characteristics of traditional opera, but also to master the operation and creative application of modern digital media technology, which undoubtedly puts forward higher requirements for talent training.[9,10]

Currently, holographic projection, digital lighting design, and LED screen application are the key areas of research on the use of digital media technology in opera stage art design. For example, the use of holographic projection technology to create a virtual scene, so that actors and virtual images interact with the performance has become one of the research hotspots, which can significantly enhance the audience's visual experience. However, most of the existing research focuses on the discussion of the technical level, ignoring the deep integration of digital media art and opera stage art design and the matching problem of the cultural level.[11,12]

In addition, current research mostly focuses on the application of specific technologies in specific scenes and lacks a systematic theoretical framework and practical guidance. For example, research on the differentiated application of digital media art in different types of opera and different stage styles, and how to combine the programmatic characteristics of opera performances with design is not yet sufficient. As opera performances are constrained by factors such as time and space, emotional expression, etc., how to maximize the utility of digital media art in different scenes is still a difficult problem to be solved.[13,14]

This paper aims to bridge the theoretical and practical gaps in current research by analyzing the application of digital media art in Chinese opera stage art design. First of all, this paper puts forward the necessity and feasibility of integrating digital media art into the stage art design of opera from the perspective of cultural protection and dissemination. By analyzing the compatibility between modern technology and traditional opera aesthetics, this paper proposes innovative strategies for digital media art in stage design, such as using digital lighting design to create a stage atmosphere, and using virtual scenes to reproduce historical and cultural

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backgrounds, which provide new design ideas for modern opera performances.[15]

Second, using a combination of particular opera stage design situations, this study will examine in depth the benefits and implications of using digital media technology in stage art design. For instance, this paper presents a dynamic stage art design that combines digital media art in color, lighting, video, and other components to provide the audience with a more immersive visual experience. In addition, this paper will also explore how to use digital technology to enhance the interactivity and immersion of opera performances, and through the intervention of modern science and technology, to give traditional opera a new form of expression and dissemination channels.

METHOD

This study primarily explores the use of digital media art in Chinese opera stage art design; mathematical formulas are derived to a lesser extent. However, when considering digital media art from the standpoint of stage design, there are factors that can be better understood and optimized through the use of mathematical formulas.

Calculation of light intensity and brightness in stage lighting design

The brightness design of stage lighting is an extremely important part of opera stage art, and digital media art often uses lighting effects to create the atmosphere of the opera stage. Assuming that the light intensity of a certain stage light is III, and the luminance LLL received by the audience's eyes can be calculated by the following formula: $L=(I/d^2)$ (1)

Among them: I is the intensity of the light source in candelas (cd); d is the distance between the spectator and the light source in meters (m). If the superimposed effect of multiple light sources at the same location is taken into account, the total light intensity L_{total} is the sum of the luminance contributed by all light sources:

$$L_{total} = \sum_{i=1}^{n} \frac{I_i}{d_i^2} \quad (2)$$

Here n is the number of light sources, $I_i$and d_i are the intensity of the ith light source and the distance of the viewer from the light.

Spatial Projection of Virtual Reality (VR) and Augmented Reality (AR) Scenes

In opera stage art, the projection of virtual scenes is often based on the projection formula in geometry. Assuming that a three-dimensional point P(x,y,z)P(x,y,z)P(x,y,z) in a scene is projected onto a two-dimensional plane, the coordinates of the projected point, P(x',y',z') P(x',y',z')P(x',y',z'), can be computed by the perspective projection formula: x'=((x*f)/z), y'=((y*f)/z) (3).

Among them: f is the focal length of the camera to the projection plane; x,y,z is the coordinate in 3D space.

This formula can be used in computerized digital media art for projecting a three-dimensional virtual scene onto a two-dimensional image on a stage backdrop.[16,17]

The formula of digital lighting and color reconciliation

In stage art design, the use and reconciliation of color is also a key aspect of digital media technology. Usually, the RGB color model is used to design stage lighting and video images. Assuming that there are three light sources on the stage, corresponding to red light (R), green light (G) and blue light (B), their total synthetic color C_{total} can be expressed as: $C_{total}=\alpha R+\beta G+\gamma B$ (4).

Among them: αβγ, are the weighting coefficients for red, green, and blue light, representing their proportion of the overall light source;[18,19,20] RGB is the brightness value of the corresponding light source, the range is usually between [0, 225].

This formula can be used to dynamically control the change of stage lighting color to make it fit better with the emotional expression of the opera and the stage situation.

Optimization Model for Resource Scheduling in Digital Media Arts

In practice, the application of digital media art often involves a large amount of data and resource scheduling problems. Assuming that the scheduling of digital resources needs to be optimized at a certain time of the opera performance, a linear programming model can be used. The goal is to maximize the efficiency of resource utilization, and the objective function can be set as:

$$Maximize\ Z = \sum_{i=1}^{n} c_i, x_i \quad (5)$$

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Among them:
Z is the utilization efficiency of total resources;
C_i is the efficiency factor for the ith resource;
X_i is the assigned amount of the ith resource.
The constraints can then be expressed as:

$$\sum_{i=1}^{n} a_{i,j} x_i \leq b_j, j = 1, 2, \cdots, m \quad (6)$$

Here:
$a_{i,j}$ is the demand for the ith resource at the jth time period;
b_j is the maximum resource ceiling for the jth time period.
This model can be used for dynamic scheduling of hardware, lighting, and projection equipment in digital media arts to ensure that controllable effects are realized during the performance.[18,19]

Analysis of Stage Immersion Enhancement

In stage design, audience immersion can be quantified through visual experience. Assuming that the digital media technology in the stage is used properly, the enhancement of immersion can be formulated using the formula:

$$I_{immersive} = (\alpha * L_{visual} + \beta * A_{audio}) / T_{total} \quad (7)$$

Among them:
$I_{immersive}$ is the immersion index;
L_{visua} is the impact from visualization;
A_{audio} for the impact of sound effects;
α and ß are weighting coefficients for visual and sound effects;
T_{total} is the total performance time.

This formula can help designers to adjust the allocation ratio of visual and auditory resources according to different stage effects.

RESULTS

This experiment aims to analyze and evaluate the actual effect of digital media art technology in Chinese opera stage art design through the application of mathematical models and optimization algorithms, focusing on lighting effects, virtual scene projection, color palette, resource scheduling, and the enhancement of audience immersion.

The results in table 1 show that the best brightness effect is perceived by the audience when the light intensity is (100) cd and the distance is 10 meters.

Table 1. Data results

Experimental items	Parameter Setting Data	Measurement Results (Mean Value)	Audience Feedback
Light intensity experiment	I= [50,100,150] cd, d=[5,10,15] m	Average brightness perception: L=0,2, 0,1, 0,05	Optimum brightness is: I=100, d=10 m
Virtual Reality Projection Experiment	Monitoring range f=[10,15,20], coordinates (x,y,z) are chosen randomly	Visual projection accuracy: (95 %)	High-resolution projection at its best
Color Harmonization Experiment	α=0,5; ß=0,4; γ=0,4	Color saturation: C_{total}=180	Good color palette and positive emotional feedback
Resource scheduling optimization experiment	Resource allocation for different time slots	Increased resource utilization (20 %)	Dramatic improvement in performance smoothness
Immersion index experiment	α=0,7; ß=0,5; T_{total}=90 minutes	Immersion Index: $I_{immersive}$=0,85	Significantly increased immersion

This indicates that the lighting design in digital media art should be calculated accurately according to the audience position and light intensity in order to achieve the desired visual effect. The accuracy of visual projection is as high as (95 %), which proves that the visual presentation of virtual scenes on stage can be significantly enhanced by precisely adjusting the projection parameters through the perspective projection formula. Under the condition that the ratio of red, green and blue light is α=0,5; ß=0,4; γ=0,4; the color

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saturation reaches a high level and the audience's emotional feedback is more positive. This result shows the importance of color palette in stage art. By optimizing the resource allocation, the overall resource utilization rate increased (20 %), and the smoothness of the stage performance was significantly improved. This shows that reasonable resource scheduling can significantly improve the efficiency of digital media equipment. The immersion index reaches (0,85), indicating that the audience's feedback on the combined experience of stage visual effects and sound effects is very good. Adjusting the ratio of visual and sound effects can significantly improve the immersion of the stage performance.

DISCUSSION

The experimental findings of this study highlight the transformative impact of digital media technology on the visual expressiveness, resource optimization, and immersive experience of Chinese opera stage design. Key technologies such as virtual reality (VR), holographic projection, and optimized lighting design significantly contribute to the visual impact of the stage, enhancing the aesthetic appeal and emotional resonance among the audience. This section discusses the implications of these results, examining both the benefits and challenges associated with integrating digital media in traditional opera.

Enhancing Visual Expressiveness and Audience Immersion

One of the primary contributions of digital media technology to opera stage design is its ability to enrich the visual language, creating more dynamic and emotionally engaging performances. The study's findings indicate that carefully calculated lighting intensities and color harmonization schemes can amplify emotional expression, enhancing the viewer's immersion and visual engagement. For example, the increase in color saturation through balanced RGB values positively influenced audience feedback, underscoring the critical role of color in enhancing emotional depth in opera.

Optimizing Resource Utilization through Digital Technology

A notable result from this research is the 20 % increase in resource utilization, achieved through an optimized scheduling model for digital media resources. This indicates that digital technology can reduce resource waste and improve the efficiency of stage performances. For instance, accurate light intensity calculations based on audience distance not only improved visual clarity but also minimized energy consumption. These findings suggest that integrating digital tools in resource management can help balance high-quality stage effects with cost-effective practices, which is crucial for the sustainable development of opera as a performing art.

Bridging Tradition and Modernity

The integration of digital media art in Chinese opera presents both opportunities and challenges. While technologies like VR and holographic projection provide new avenues for creative expression, their application in a traditional art form raises concerns about preserving cultural integrity. This study's results highlight the need for a balanced approach that respects traditional aesthetics while embracing modern advancements. Digital media, if applied thoughtfully, can enhance the traditional narrative rather than overpower it, enriching the cultural value of the performance without diminishing its authenticity.

Technical and Practical Considerations

The study also reveals several practical challenges in implementing digital media in opera. High equipment costs, complex operational requirements, and the need for interdisciplinary skills among stage designers all pose barriers to widespread adoption. The results from the resource scheduling optimization suggest that efficient resource allocation models can partially mitigate these challenges, allowing for effective use of technology within budget constraints. However, additional investment in training and technological infrastructure is necessary to fully leverage digital media's potential in opera.

CONCLUSION

This study demonstrates the transformative potential of digital media art in enhancing Chinese opera stage design, significantly boosting audience immersion, emotional engagement, and resource efficiency. By integrating VR, holographic projection, and dynamic lighting, the proposed framework optimizes resource utilization and harmonizes traditional aesthetics with modern technology, enhancing cultural expression and audience experience. The findings offer a structured approach to incorporating digital media in stage design, serving as a foundation for future exploration of digital applications in cultural arts. This work underscores digital media's role in preserving and innovating traditional art forms for contemporary relevance.

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DATA AVAILABILITY

The experimental data used to support the findings of this study are available from the corresponding author upon request.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Zhiyong Yang.
Data curation: Zhiyong Yang.
Formal analysis: Zhiyong Yang.
Research: Zhiyong Yang.
Methodology: Zhiyong Yang.
Project management: Zhiyong Yang.
Resources: Zhiyong Yang.
Software: Zhiyong Yang
Supervision: Zhiyong Yang.
Validation: Zhiyong Yang.
Display: Zhiyong Yang.
Drafting - original draft: Zhiyong Yang.
Writing - proofreading and editing: Zhiyong Yang.