Trends in Social Sciences and Humanities Research
Print ISSN: 2959-992X
Online ISSN: 2959-9938
DOI: https://doi.org/10.61784/tsshr3200

TECHNOLOGICAL INNOVATION IN CHINESE OPERA FILMS SINCE THE NEW CENTURY

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Abstract: As a unique genre of Chinese cinema, opera films have always undertaken the mission of inheriting traditional Chinese culture. Since the new century, the explosive development of digital technology has broken its rigid paradigm of "stage recording" and promoted media reconstruction and aesthetic transformation. This article explores the paths of technological innovation in opera films from three dimensions: technological aesthetics, the integration of 3D/VR/XR technologies, and image empowerment with technological breakthroughs. The findings show that digital technology not only reconstructs the spatial, soundscape and narrative logic of opera, but also revolutionizes the production process, audience-performer relationship and communication field through in-depth integration with emerging technologies. The essence of technological innovation lies in the self-adaptation and proactive evolution of traditional culture in the digital age, with its core being to uphold the ontological aesthetics of opera, find a precise balance between technological rationality and artistic sensibility, and ultimately help opera art achieve creative transformation and innovative development in the contemporary context.
Keywords: Opera films; Digital technology; Technological innovation; Innovative development

1 INTRODUCTION

Chinese opera film is a unique genre in Chinese cinema, and its development trajectory has always been centered on traditional Chinese culture. Evolving alongside the advancement of modern technology, this cross-media art form has embodied a dual mission since its inception: it must not only preserve the stylized aesthetics of traditional Chinese opera, including its singing, recitation, acting, and acrobatics (collectively known as "chang, nian, zuo, da" in Chinese opera terminology), but also adapt to the narrative characteristics of film' s camera language. Chinese opera film is thus a product of the symbiotic integration of these two artistic forms that operate on parallel paths. The virtuality and stylized performance of opera collide and merge with the realism and documentary nature of film, forging the unique presentation style and aesthetic traits of Chinese opera film.

Since the new century (i.e., since 2000), the rapid development of digital technology has endowed this symbiotic relationship with a new dimension of interpretation. When HDR technology—with its expanded dynamic range—digitally enhances the colors of opera costumes; when action cameras and motion capture technology reconstruct the postures and movement trajectories of martial arts performers in opera; when virtual production materializes the abstract imagery in opera; and when stereophonic sound fields create a surround effect for virtual stages, the rigid "stage recording" paradigm that once defined the creation of Chinese opera film has been quietly broken by technological progress. In this new era, technology has begun to question the ontological essence of Chinese opera film. What new technology enables is not merely a simple additive application of technical tools, but a media reconstruction with cultural production significance that aligns with the core logic of remediation theory. Specifically, digital film—this "new medium"—creatively reshapes the expressive forms and perceptual dimensions of opera while preserving the core aesthetic traits of opera as an "old medium."

In Chinese opera films of the new century, the application of digital technology has not only transformed the way these films are created and presented, but also redefined the existential form of "operatic nature" without diluting the essence of opera. For instance, 120-frames-per-second slow-motion photography extends the time and space of unique opera sequences such as feather fan techniques and water sleeve movements. It converts the subtle, fleeting details that audiences once had to "catch from a distance" and "perceive through imagination" on traditional stages into clearly observable, delicate movement trajectories on the screen, allowing the rhythmic and technical nuances of operatic stylization to be presented more intuitively. The integration of Dolby Atmos has broken the limitation of the "single sound field" on traditional opera stages; it deconstructs and reorganizes the timbres of traditional instruments like the jinghu (a two-stringed fiddle unique to Peking Opera) and banhu (a high-pitched bowed string instrument widely used in Chinese folk operas) within an auditory space, creating an immersive surround sound experience and endowing the layered texture and expressive power of opera music with a new dimension of expression. The new grammatical system of Chinese opera film constructed collectively by these technical elements is, in essence, the remediation of opera art through the medium of digital film.

Technological upgrading has driven the systematic reconstruction of the production ecosystem, which is mainly reflected in the interactive matrix of production processes, narrative dimensions, and reception arenas. For example, virtual production technology has broken the linear production model of traditional Chinese opera films—where "stage performance comes first, followed by filming"—and this technological innovation has addressed the issue of relative

separation between stage space and camera space that once existed in traditional Chinese opera films. From an industrial development perspective, technological empowerment can also reduce the production costs of Chinese opera films, improve production efficiency, and expand market share. “The integration of digital technologies has simplified the overall production workflow of traditional Chinese opera films while boosting operational efficiency[1].” Diverse communication channels and marketing methods have also provided more opportunities for the market promotion of Chinese opera films. As an important contemporary carrier for the dissemination of opera art, Chinese opera film needs to leverage technological means to achieve modern transformation, thereby promoting the broader dissemination, inheritance, and development of opera art.

2 Technological Aesthetics of Chinese Opera Films Since the New Century

Traditional opera art features highly stylized aesthetic characteristics, with its performance, singing, and other elements following strict norms and conventions. However, against the backdrop of a modern society with diverse cultures, this aesthetic paradigm is facing a disconnect from the aesthetic concepts of contemporary audiences. The involvement of digital technology has broken the single stylized aesthetic model of opera art, promoting its development toward a more diversified aesthetic direction and reconnecting traditional aesthetics with modern concepts.In the historical context of the new century, the technological revolution, like a powerful engine, has driven the iterative transformation of Chinese opera films in terms of aesthetics. 2019 film Catching and Releasing Cao became the world' s first 8K Peking Opera film with panoramic sound. Through ultra-high-definition images and rich sound effects, the film offered an unprecedented viewing experience. This work not only preserves the classical Peking Opera performance but also enriches its artistic expression through modern technology, opening new possibilities for the future of Chinese opera films[2]. This has not only rewritten the industrial production paradigm of films but also left the mark of the times in the creative and production process of Chinese opera films. Different from other film genres, Chinese opera films must not only uphold the traditional artistic genes of opera but also reconstruct the screen' s expressive language through digital technology. This aesthetic evolution is not a one-way transformation of the art; instead, it fosters a new aesthetic form that integrates the expressive language of opera art with the contemporary visual context.

2.1 The Reconstruction of Opera Space Through Digital Technology

Since the turn of the new century, digital technology has intervened in the field of Chinese opera film with unprecedented force, triggering profound transformations in the aesthetic space of Chinese opera. “The cinematic translation of stage concepts is not only intended to integrate with the stage art of traditional opera, but more importantly, to create a kind of beauty that can resonate emotionally with the audience[3].” The technical and aesthetic transformation of Chinese opera film is, in essence, a cinematic translation of the assumptive aesthetics of traditional Chinese opera. Technology reshapes the original aesthetic space of Chinese opera, gives rise to new artistic forms and aesthetic experiences, breaks the physical boundaries of the traditional Chinese opera stage space, expands the expressive dimensions of performances, and reconstructs the temporal and spatial logic of narration—allowing Chinese opera film to exhibit entirely new aesthetic characteristics through the integration of technology and art. The aesthetic principle of "using virtuality to represent reality" in traditional Chinese opera has been reinterpreted with the support of digital technology; in terms of audio-visual language, the rapid development of digital technology has also brought boundless possibilities for showcasing the charm of Chinese opera art.

Constrained by film shooting methods and optical processing technologies, traditional Chinese opera films had limitations in image clarity, color richness, and scene construction. The emergence of digital technology, however, has broken these original constraints throughout the pre-production, production, and post-production stages of Chinese opera film creation. Digital cinematography can accurately capture the vivid expressions of opera performers and their body language with narrative and expressive significance, conveying the unique "freehand" beauty of Chinese opera to audiences in a more delicate manner. The traditional "one table and two chairs" stage space has undergone a paradigm shift from a "two-dimensional" to a "three-dimensional" form through digital technology; the narrative dimension has also evolved from linear to three-dimensional, and from single-faceted to diverse. The reconstruction of Chinese opera' s narrative space by digital technology is also reflected in the detailed depiction of scenes and the creation of atmospheres. High-precision digital modeling and light rendering enable scene details and atmosphere to reach a level of refinement that traditional stages could hardly achieve—this not only enhances the sense of realism and immersion in narration but also endows Chinese opera film with more diverse aesthetic expressions.

The aesthetic space of Chinese opera reconstructed by digital technology represents the "diversified manifestations" of traditional art in the digital era. Breaking down and reconstructing existing concepts not only preserves the original essence of Chinese opera as "telling stories through singing and dancing" but also expands its expressive timeline through technical media. When Chinese opera film reconstructs its aesthetic space in the digital dimension, it not only accomplishes the media transition from stage to screen but also achieves a creative transformation from the aesthetic paradigm of agricultural civilization to the aesthetic system of the digital age. However, technical reconstruction also harbors aesthetic risks: excessive intervention of digital effects in the core of performances may dilute the fundamental value of Chinese opera, which lies in "driving the story through performers"; when immersive experience replaces aesthetic distance, it may weaken the philosophical implication of "calm observation and quiet contemplation" in

Chinese opera. Therefore, creators must maintain aesthetic awareness toward traditional culture in the application of technology.

2.2 Application of Spatial Montage in Opera Films from the Perspective of Technological Aesthetics

Before the involvement of digital technology, the spatial aesthetics of opera films were constrained by the dual opposition between "stage recording" and "film grammar". The spatial design of traditional opera stages adheres to the aesthetic principles of "virtuality, stylization, and impressionism", where the narrative space is co-constructed by the performers' actions and the audience' s imagination. The integration of digital technology, however, has enabled opera films to break free from physical limitations in spatial expression, creating a "beyond-stage" visual spectacle.

Early opera films mostly relied on medium shots with fixed camera positions, attempting to replicate the "fourth wall"—an inherent element of the traditional audience-performer relationship—in the two-dimensional screen. While this replicative approach preserved the integrity of opera art, it failed to achieve an organic fusion of the two art forms. In the 3D spatial audio opera film Farewell My Concubine, digital technology transforms the historical scenes of the Chu-Han rivalry into a rotatable and penetrable three-dimensional space. During Yu Ji' s sword dance sequence, the combination of dynamic camera movements and virtual scenes extends the traditional "circular stepping" technique into an epic visual trajectory within the 3D space. This technical treatment is not a mere copy of stage performance; instead, it converts the "linear timeline" of opera performance into a "three-dimensional spatial field" through spatial montage. The close-up shots of Xiang Yu and Yu Ji toasting for the last time allow the audience to clearly see the tears welling up in their eyes—a detail never before so vividly presented. This "single tear" in Farewell My Concubine symbolizes a new horizon for the "new Peking Opera film" genre.

Technological empowerment has also facilitated in-depth integration between the stylized virtuality of opera and the spatial montage thinking of film. In the Cantonese opera film The Legend of the White Snake, post-production special effects turn the stylized "water sleeves" (a traditional opera prop) into a concrete digital torrent. “The film presents the digital "ink wash-style Chinese aesthetics[4].” A milestone of new-age xiqu cinema, White Snake actively responds to the changing circumstances of emerging technologies and young people' s zeal for traditional culture, blurring the boundary between revered heritage and popular cultural product[5]. The support of IMAX technology further enhances the immersive quality of spatial montage in opera films. For instance, in the Peking Opera film Cao Cao and Yang Xiu, IMAX' s ultra-large format showcases the grand space of Cao Cao' s military tent, while a rapid zoom-in shot focuses on the bamboo slips in Yang Xiu' s hands—these slips then transform into swirling snowflakes. The camera then pulls back to reveal a snowstorm-shrouded ancient battlefield. This spatial transition from micro to macro breaks the distance between audience and stage in traditional opera, allowing viewers to both catch the subtle facial expressions of performers and feel the grandeur of the battlefield.

Spatial montage empowered by technology elevates opera performance from "linear narration" to "spatial poetics" while preserving the essence of stylized aesthetics, thus achieving the creative transformation of traditional art. Here, spatial montage serves not only as a narrative tool but also as an aesthetic strategy to reshape the audience-performer relationship in opera films. This technical practice also validates Marshall McLuhan' s theory of "the medium is the message": digital technology not only changes the presentation form of opera films but also reshapes their aesthetic essence—transforming the "distant virtual stylization" of opera into a tangible "immersive aesthetics" that the audience can perceive directly.

The evolutionary path of technological aesthetics reveals the dual dimensions of space in opera films: horizontally, digital technology breaks down the physical boundaries between stage and screen, and the resetting of media interfaces enables the multi-dimensional deconstruction and reorganization of stylized performances; vertically, the construction of immersive fields integrates the audience into the narrative system of opera films, achieving a paradigm shift in aesthetics from "alienation between audience and performance" to "emotional immersion" through the technical extension of synaesthesia. This represents opera films' reaffirmation of their own artistic essence in the digital age of the 21st century. When the stylized virtuality of opera meets the digital space of film, the sparks generated open up new narrative possibilities for opera art in the context of technological reconstruction.

Practice of opera films since the 21st century has shown that the application of spatial montage is not a deviation from opera aesthetics, but rather a balance struck between technical rationality and artistic sensibility. In terms of technological empowerment, films leverage advanced technologies to bring out the delicate details of Kunqu opera aesthetics. 8K ultra-high-definition technology presents subtle details that are easily overlooked on stage—such as the curvature of water sleeves, changes in finger movements, facial expressions (e.g., Lu Sheng' s tipsy look in his dream and his realization upon waking), clothing patterns, and the texture of props—turning the Kunqu principle of "conveying spirit through form" from an abstract perception into an intuitive visual experience. Spatial audio technology accurately reproduces the layered vocal expressions of Kunqu (including the singer' s breath and the timbre of musical instruments) as well as environmental sounds, avoiding the audio overlap issues common in traditional productions. Furthermore, it uses spatial sound to guide emotions, allowing the "emotion transmission through vocals"—a unique feature of Kunqu—to transcend the auditory dimension and achieve dual audio-visual immersion.

When digital technology can accurately capture the graceful trajectory of water sleeves, and when moving shots can perfectly present the acrobatic movements in martial scenes, the spatial narration of opera films is undergoing an aesthetic leap from "reproducing the stage" to "creating the screen". This leap requires both a deep understanding of

opera traditions and the creative application of film technology. Only through the positive interaction between the two can the artistic realm of "technology serving opera, and aesthetics renewed by technology" be truly realized. The development of spatial montage not only demonstrates the technological progress of opera films but also reflects the cultural awareness of traditional art in its self-renewal during the digital era.

2.3 Aesthetic Modal Transformation of Soundscape Engineering and Opera Rhythm

The tide of technology is impacting the field of film and television art with unprecedented force, and opera films—an unique artistic form embodying traditional opera culture and modern film-television technology — are constantly undergoing the transformation of aesthetic paradigms. As a key technical manifestation of the film industry in the digital age, soundscape engineering' s collision and integration with opera rhythm form a crucial entry point for understanding the aesthetic transformation of contemporary opera films. Traditional opera is a comprehensive art based on "telling stories through singing and dancing," with its core sound system including arias, recitatives, accompaniment by civil and military orchestras, and stage effect sounds, forming the unique rhythmic aesthetics of opera. Its sound presentation often follows the acoustic spatial aesthetic principles of opera stages, emphasizing "freehand brushwork" and "stylization." Arias pursue "clear articulation and mellow tone" and "expressing emotion through sound," with each segment bearing the functions of character emotional expression and plot advancement. Its rhythmic patterns are closely linked to opera' s beat patterns, forming a fixed yet elegant framework. Constrained by the two-dimensional flatness of physical venues, the soundscape construction of traditional opera stages has always wandered and changed along the axis of "stage entrance-audience seating." Multi-channel recording technology in soundscape engineering is an emerging technical field integrating acoustics, psychology, aesthetics and other disciplines. It collects different sound sources through multiple microphone positions and conducts precise spatial positioning and mixing in post-production; “The advent of Dolby Atmos has freed auditory effects from mere dependence on visual presentation, allowing them to exist as a more authentic and immersive relay element within the film[6].” The Peking Opera film Cao Cao and Yang Xiu has adopted a full set of state-of-the-art Dolby Atmos production workflows, and engaged Roger Savage—an Oscar-winning British sound production master — to oversee the Dolby Atmos sound design[7]. The soundfield positioning of the traditional "Three Major Instruments" ensemble has been transformed into the distribution of a 3D soundscape particle map, while the original fixed instrumental tracks have evolved into a rhythmic matrix of independent tracks surrounding the audience. This acoustic technological innovation does not deviate from the intrinsic aesthetics of traditional opera art; instead, it leverages digital technologies for sound image displacement to control and regulate the audio, creating a more three-dimensional auditory space for the "Xipi and Erhuang" arias within the metric structure of Peking Opera. It not only preserves the traditional charm of opera but also aligns with the rhythmic logic of film narrative.

Soundscape engineering can also creatively combine and process different sound materials to realize the innovative expression of opera rhythm. For example, in wind and rain scenes, realistic wind and rain sounds blend with arias and accompaniment, enhancing artistic appeal and immersion; rhythmic changes based on fixed beat patterns and performance modes break traditional rigid frameworks, offering unlimited possibilities for the richness of opera rhythm. In the soundtrack of the Cantonese opera film The Legend of the White Snake, modern electronic sounds interweave with the timbres of traditional instruments such as the gaohu and yehu. While preserving the metrical rules of opera music, it creates a soundscape conforming to modern aesthetics, breaking through "protectionist" thinking and integrating historical charm with new-era aesthetics. This soundscape revolution goes beyond the superficial significance of technical upgrading, allowing the audience to hear the frequency of technological innovation while truly feeling the resonance of inheriting fine traditional Chinese culture in the interweaving of virtual and real soundscapes. The rhythmic transformation driven by soundscape engineering triggers dual effects at the aesthetic level: digital technology expands the expressive dimensions of opera vocals, endowing traditional recitatives with new spatial narrative capabilities in the panoramic sound field; at the same time, excessive technical processing may lead to opera aesthetics becoming a subsidiary of "sound effects." As Dolby Atmos reshapes the acoustic dimensions of "Xipi" and "Erhuang" tunes, and AI algorithms deconstruct the pronunciation rules of "four articulation methods and five vowel categories," opera films are undergoing an aesthetic transformation from "stage recording" to "acoustic installation." Practitioners of opera films must maintain reverence for the essence of opera while transcending technological determinism, exploring paths for the modern transformation of traditional art in the gap of modal transformation. Future soundscape design of opera films may open up a "new vocal" aesthetic system belonging to the digital age through the balance between technical rationality and artistic poetry.

In the digital era, the audience' s aesthetic needs present diverse and personalized characteristics. They pursue fresh and exciting visual experiences, emphasizing emotional resonance and interactivity. Through innovative creation of opera films, digital technology accurately meets these aesthetic needs of modern audiences. Technology-driven aesthetic transformation is a process of reconstructing artistic ontology by digital media. Opera films are no longer confined to the simple superposition of "combining opera with film" through cinematic forms; instead, under the combined effect of technology, creation and even algorithms, they have spawned a third-state artistic form with digital aura. This transformation not only inherits Mr. Mei Lanfang' s innovative spirit of "moving forward without changing essence" but also uses technology as a fulcrum to promote the modern transformation of the entire aesthetic system of opera art.

3 Technological Integration of Opera Films with 3D/VR/XR

Since the new century, the iteration and upgrading of digital technology have opened up multi-dimensional paths for the development of opera films. When technologies such as 3D, VR (Virtual Reality), and XR (Extended Reality) meet opera art, they not only trigger innovations in creative tools and presentation forms but also drive the in-depth reconstruction of opera films from the audio-visual language system to the audience-performer relationship. This technological integration explores the transformation possibilities of traditional opera art in contemporary audio-visual space through the collision between the aesthetic characteristics of opera and the properties of digital technology. What audiences perceive in three-dimensional images is not only the expansion of spatial dimensions but also the digital extension of the free nature of opera's time and space.

3.1 3D Technology: A Spatial Dialogue Between Stereoscopic Imaging and Traditional Opera Conventions

The spatial presentation of traditional opera films has long grappled with the dual tension between the operatic stage nature and the cinematic camera perspective. Since the birth of Dingjun Mountain in 1905, opera films have constantly sought a balance between "stage recording" and "cinematic adaptation." Early works mostly adopted fixed-camera stage documentation, with spatial movement confined by the physical boundaries of the theater. After the founding of New China, films such as Legend of the White Snake (1956) attempted to deconstruct the stage structure through montage, breaking free from temporal and spatial limitations. However, the two-dimensional flat image carrier still struggled to fully convey the spatial poetics of opera performances—virtual spaces constructed through stylized movements (e.g., "horse-trotting" gestures symbolizing a long journey, whip-flicking representing riding) often lost their freehand artistic qualities when concretized in real shooting scenes.

The introduction of 3D technology first revolutionizes opera films through breakthroughs in spatial dimensions. Traditional opera films, restricted by the physical boundaries of the flat screen, usually express stage space symbolically through axis movement and depth-of-field shots. In contrast, 3D technology, based on the principle of binocular parallax, transforms the virtual time and space of opera into a perceptible three-dimensional field. This transformation is not a mechanical reproduction of the stage space but a creative translation of opera' s aesthetic characteristics enabled by digital technology. The technical features interact subtly with the virtuality of opera performances: the three-dimensional image space not only enhances the visual impact of operatic movements—for example, acrobatic skills like somersaults and spins in Peking Opera martial scenes gain more striking dynamic expressions through 3D effects—but digital modeling also allows creators to construct interwoven virtual-real spatial scenes according to narrative needs. The digital reproduction of the opera stage in the 3D opera film Xiao He Chases Han Xin Under the Moon creates a surreal symbolic space using CG technology.

This three-dimensional reconstruction of spatial narration is essentially a contemporary interpretation of Bazin' s theory that "cinema is an asymptote of reality," reconciling the "alienation effect" of opera performances with the "immersive experience" of cinema. Technologically empowered spatial narration does not diminish the virtuality of opera; instead, through three-dimensional visual language, it establishes new visual logic for stylized virtual movements in a three-dimensional space. Meanwhile, the real physical space is elevated into a poetic image space by the freehand spirit of opera.

3.2 VR Technology: A Perceptual Revolution in Audience-Performer Relations and Immersive Experiences

If 3D technology represents the vertical expansion of screen space, VR (Virtual Reality) technology eliminates the "fourth wall" of traditional viewing spaces and constructs a fully immersive interactive environment. Through virtual theaters created by head-mounted displays, VR technology breaks the physical barrier in traditional audience-performer relationships, allowing audiences to achieve a "front-row" immersive experience in cyberspace. Its core features are "presence" and "interactivity." The integration of VR technology transforms opera films from "an art of viewing" to "an art of experience," a shift that poses a fundamental challenge to the traditional audience-performer dynamic of opera. Audiences evolve from passive observers in front of the screen to "present participants" in virtual scenarios, and this revolution in audience-performer relations prompts a rethinking of the essence of opera films.

In immersive experiences, audiences gain subjective and multi-dimensional perspectives of the opera stage, deconstructing the limitations of camera angles in traditional opera films. They can even interact with virtual props (such as tables and chairs on the stage, or rockeries in gardens) through controller operations. The transformation of audience-performer relations inevitably leads to adjustments in narrative strategies—details that might be overlooked in traditional camera shots become crucial for conveying the narrative tension of opera under VR' s close-up observation. While traditional opera films rely on directors' cinematographic language to guide audience attention, VR narratives require the construction of open spatial narrative structures, where interactive designs grant audiences limited participation in the narrative. Through haptic feedback devices and motion capture systems, VR technology enables audiences to obtain an embodied perceptual experience similar to watching a live opera performance. When a character performs a stylized "freeze" move like a stance, audiences can feel the vibration of the ground through haptic feedback; in martial arts scenes, the sound of clashing weapons changes direction with the rotation of the audience' s head. The synergy of these multi-sensory perceptions transforms the "symbolism" of opera performance into tangible bodily memories through digital technology, realizing the identity shift of "audience as performer" in virtual space.

The "stylization" of opera performance faces dual challenges in VR spaces. Technology' s impact on opera films extends beyond the form of viewing and performance to touch the core realm of opera aesthetics. High-precision

motion capture technology can perfectly reproduce performers' stylized movements, such as water sleeve and beard techniques, and even allow audiences to "feel" the weight of water sleeves through force-feedback gloves. However, fully immersive virtual scenarios may obscure the traditional "conventionality" inherent in opera—when a virtual garden is more exquisite than a real one, and a digital avatar is more perfect than the performer themselves, will the aesthetic space of opera, built on imagination, be replaced by the "reality" constructed by technology?

From the perspective of reception aesthetics, VR opera films are cultivating the aesthetic cognition of a new generation of audiences. For Generation Z, the viewing mode that requires active exploration aligns better with the behavioral habits they developed through digital games. This cognitive transformation is not only a technological innovation but also an important path for the intergenerational inheritance of opera art in the digital age.

3.3 XR Technology: The Coexistence of Reality and Virtuality in Traditional Chinese Opera

XR (Extended Reality), as a technological integration integrating AR (Augmented Reality), VR (Virtual Reality), and MR (Mixed Reality), is breaking the inherent boundaries of traditional media, creating cross-dimensional narrative possibilities for traditional Chinese opera films. If 3D represents the vertical extension of screen space and VR the construction of enclosed virtual spaces, XR is committed to breaking down the barriers between the real and virtual worlds. It allows traditional opera art to intervene in the viewer's real world in a more extensible form, overlaying virtual opera elements onto real scenes to build a mixed reality theater where reality and virtuality converge. This not only expands the communication field of traditional opera films but also opens up new channels for cultural inheritance.

The innovation of XR technology in reshaping the creative paradigm of traditional opera films is also reflected in the practice of "Transmedia Storytelling." Traditional opera films are closed narrative texts, while XR-based opera works have become open narrative systems. XR technology promotes a shift from "director-centered" to "user-centered" approaches in opera films, emphasizing the process of embodied cognition. It transforms the linear, preset creative process of traditional films; XR works need to preset multiple interactive paths and consider the impact of user behavior on narratives. This requires creators to possess "spatial narrative thinking," converting the temporal narration of opera into spatial experiences.

In the field of cultural heritage preservation, XR technology has enabled the "digital rebirth" of traditional opera art. Through laser scanning and motion capture technologies, performance data of master artists like Mei Lanfang have been transformed into interactive digital models. The XR Opera Exhibition launched by the Chinese Opera Museum creates a fantasy "stage" through virtual reality and integrates "hundreds of operas" with digital light and shadow, expanding new scenarios of "metaverse + opera." By combining classic opera elements with national animation, it presents traditional cultural stories in a dreamlike wonderland. Visitors can immerse themselves in the vivid oriental aesthetics within the "pavilions and towers" of the museum. Technological practices have transformed the "museum-style" preservation of opera art into "dynamic inheritance," reconstructing the inheritance mechanism of cultural memory in cyberspace. When digital technology can revive the stage images of deceased artists and AI can simulate the vocal characteristics of genre founders, the "dynamic inheritance" of opera has gained new technological carriers. At the same time, it raises ethical discussions about artistic authenticity: Do virtually generated performances belong to opera inheritance? Can technically replicated vocals carry the spiritual core of artistic genres?

Traditional Chinese opera is "telling stories through singing and dancing," with its aesthetic core lying in the organic unity of stylization, virtuality, and impressionism. The sensory stimulation brought by 3D/VR/XR technologies, if separated from the aesthetic foundation of opera, will ultimately become empty technological displays. As Walter Benjamin warned in "The Work of Art in the Age of Mechanical Reproduction," technological reproduction may dissolve the "aura" of art, but it also creates possibilities for art popularization. The key lies in maintaining the "ontological awareness" of opera amid technological innovation. Such awareness first manifests in adhering to the subjectivity of opera performance—no matter how technology develops, the physical expression of actors remains the core of traditional opera films. The virtuality of opera essentially "uses simplicity to replace complexity"; excessive stacking of digital effects may violate the impressionistic spirit of opera. In creating virtual opera, insisting on using real actors for motion capture instead of relying on CG generation is precisely to preserve the "dynamic" characteristics of opera performance. The curvature of Cheng Yanqiu's water sleeves and the flow of Mei Lanfang's eye expressions—these subtle, personalized differences are important carriers of the "aura" in opera art. Technology should serve as a tool to amplify this "aura" rather than replace actors.

At the intersection of technology and art, the development of traditional opera films presents unprecedented possibilities. 3D/VR/XR technologies not only change the presentation of opera but also reshape the audience's cognitive paradigm: from flat viewing to three-dimensional experience, from passive acceptance to active exploration, from screen watching to field immersion. However, all technological innovations must answer a fundamental question: When all digital effects are removed, does the work still carry the spiritual essence of opera art? Only by maintaining a dynamic balance between technological empowerment and ontological adherence can traditional opera films continue the artistic legend of "moving forward without changing essence" in the digital age. This balance is not a simple compromise but a creative transformation based on a deep understanding of opera aesthetics—allowing the ancient art of opera to grow into a new form that retains its genetic characteristics while embracing the times in the soil of new technologies.

Technological integration should not be limited to formal innovation but should touch upon the cultural functions of traditional opera films. The ultimate value of technology lies in activating the contemporary interpretive power of opera. As reflected in the overseas acclaim for technologically integrated opera films such as The Monkey King and Farewell

My Concubine, technologically empowered opera films are not only carriers for preserving traditional culture but also media for cross-cultural dialogue. When Western audiences understand not just an opera story but the philosophical wisdom of "using virtuality to represent reality" in Chinese opera, the true value of such integration is realized.

4 Visual Empowerment and Technological Breakthroughs of Traditional Opera Films

With the involvement of digital technology, traditional opera films have undergone an in-depth transformation from creative concepts to practical paradigms amid the wave of digital advancement. The reconstruction of opera images, the renewal of aesthetic perceptions and the reform of communication methods have endowed the traditional opera art with new vitality in the digital era.When the stage aesthetics of traditional opera encounter the technical logic of the film industry, their collision gives birth to a unique artistic form that is neither a mechanical reproduction of the opera stage nor a blind accommodation to film language. Empowered by technology, films have achieved the visual reconstruction of the essence of traditional opera.This reconstruction is reflected not only in the upgrading of shooting techniques but also in the paradigmatic shift of artistic thinking. Digital technology is no longer a mere instrumental carrier; instead, it deeply integrates into the narrative strategies, aesthetic expressions and communication logic of traditional opera films. While preserving the freehand spirit of traditional opera, it endows the art form with visual appeal that suits the modern viewing context.The use of digital technology is not only a technological advancement but also a revolution inaesthetics. With the help of digital technology, filmmakers are able to explore more narrative techniques and visual styles, such as virtual reality, augmented reality, and other emerging technologies, which bring unprecedented aesthetic innovation possibilities for Chinese films[8].

4.1 Modern Transformation of Traditional Opera Empowered by Digital Technology

Since the new century, the rapid advancement of digital technology has driven drastic morphological changes in traditional opera films. This technological revolution has not only restructured the ontological attributes of images in traditional opera films, but also profoundly transformed the contemporary communication paradigm of traditional opera art, realizing the ontological reconstruction and cultural value increment of traditional opera art through visual images.

With the integrated application of high-definition and high-speed photography technology, motion capture technology, and the upgrading of projection equipment, cutting-edge technologies have been widely adopted in opera films. For the Cantonese opera film Legend of the White Snake · Love, the production team used 240 frames per second slow-motion photography to capture the performers' water sleeve movements and created digital trails with ink wash textures through particle effects. The fluttering of water sleeves at the cuffs, the swaying of tassels on sword hilts, and even the subtle twitches of facial muscles are clearly presented. The "artistic conception" that relied on the audience's imagination to complement on the traditional stage has been transformed into directly perceptible "visual imagery" in high-definition images.

The Peking opera film Cao Cao and Yang Xiu, remade 30 years later as a 3D + 4K panoramic sound work, adopted full-process 3D live-action shooting technology, marking the first 3D panoramic sound 4K film produced in an end-to-end manner by SMG. The film achieved contextual dialogue between traditional Chinese culture and mainstream Western culture, making 3D panoramic sound opera films a calling card of Shanghai's cultural brands. A growing number of opera films are also combining high-definition photography with panoramic sound to present the modern charm of opera art in an all-round and immersive way. This transformation of performance paradigm is essentially the video-oriented adaptation of opera's essence empowered by technology: it retains the core aesthetic elements of singing, reciting, acting and fighting, while endowing them with more modern visual interpretations through cinematic techniques.

Technological practices have not only restructured the spatial narrative logic of opera films, but also explored new paths for the visualization of operas in the digital age through the visual language that integrates virtuality and reality. Two Cantonese opera films, The Legendary Top Scholar Lun Wenxu and Liu Yi's Adventure, boldly introduced LED technology and dynamic effect technology in scene setting. During filming, dynamic simulated backgrounds were used to incorporate the snow scenery of northern China, the mountain views of southern China, the magnificent underwater dragon palace buildings, and the beautiful landscapes of Guangdong into the images. The production team consciously controlled the realism of the special effects, enabling performers to balance their body movements and dance while realizing innovations in film language. The presentation that blends 80% realism with 20% imagination not only preserves the freehand charm of traditional opera art, but also endows the images with a poetic and romantic atmosphere.

As mentioned earlier, the opera film Madam An Guo, which adopted LED virtual production technology, transformed the traditional opera convention of "performers entering and exiting the stage from side doors" into an interactive digital space. This filming mode of "co-existing virtual and real elements" has not only resolved the long-standing imbalance between stage sense and cinematic sense in opera films, but also achieved in-depth integration of traditional opera stages with modern digital film technology, creating an unprecedented immersive aesthetic experience for traditional opera.

The technological practice of Madam An Guo shows that digital technology is not an opposite to opera aesthetics, but a carrier for the evolution of traditional artistic genes in the contemporary media environment. While expanding the expressive boundaries of opera films, technological innovation also inspires us that the contemporary transformation of

traditional art in the digital age must be based on a profound understanding of media characteristics. Only through the collaborative innovation of technological logic and artistic logic can the creative inheritance of cultural genes be achieved.

4.2 AI Technology' s Transformations to the Creative System of Traditional Opera Films

As digital technologies restructure the global film and television landscape, the integration of artificial intelligence (AI) is reshaping the paradigms of traditional artistic creation at an unprecedented pace. Traditional opera films, a crucial carrier of Chinese aesthetic spirit, are undergoing a profound transformation in their creative system—shifting from mere "technical assistance" to fundamental "cognitive reconstruction". This transformation manifests not only in the digital upgrading of production processes but also in a paradigmatic shift at the level of artistic ontology.

The shooting of the 8K Peking Opera film The Legend of the Concubine of the Tang Dynasty stands as an explorative practice that upholds traditions while pursuing innovations. By inputting the stylized norms for martial arts sequences in traditional operas, the AI system can automatically generate martial arts choreographies that conform to opera aesthetics and possess cinematic expressiveness. This technological application not only enhances creative efficiency but, more importantly, establishes a conversion interface between traditional stylization and modern imagery, providing a new methodology for the modern transformation of traditional opera films.

AI' s application in this field extends beyond the creation of new works; it also plays an indispensable role in restoring classic traditional opera films. Beijing University of Posts and Telecommunications has launched an cutting-edge micro-course themed "When Classic Peking Opera Films Meet AI". During the course, teachers and students utilized AI technology to restore and recreate a 1956 film, allowing Cheng Yanqiu—who starred in the original work at 52—to appear on screen as a young man.

Emotional expression in traditional opera performances has always relied on performers' physical control and artistic perception. AI now attempts to analyze and replicate this intricate psycho-physiological mechanism through affective computing technology. Essentially, the transformations brought by AI to the creative system of traditional opera films represent a collision between technological rationality and artistic sensibility. On one hand, the integration of algorithms boosts creative efficiency, expands expressive boundaries, and paves new ways for the modernization of traditional opera. On the other hand, excessive reliance on technology may diminish the initiative of creative subjects, erode the vivid texture of stylized performances, and even endanger the cultural roots of traditional opera art.

Currently, AI technology is applied in traditional opera films through a collaborative empowerment model. Traditional culture and its long-standing inheritance will not vanish with the emergence of new technologies; instead, they should radiate new vitality for the contemporary era with technological support. The transformations AI brings to the creative system of traditional opera films actually involve a reconstruction of the core questions: "What constitutes traditional opera?" and "What constitutes film?"

As AI algorithms start to decode the performance essence embedded in the "Four Performing Skills and Five Basic Methods", and as deep learning models attempt to simulate the underlying logic of opera aesthetics, we witness both the remarkable possibilities brought by technological revolution and the profound challenges at the level of artistic ontology. This transformation is not a mere technological upgrade, but an all-round restructuring of the entire creative system—from material foundations to value perceptions.

Technology serves as a means, while art remains the ultimate goal. In the application of AI, we must guard against the mindset of prioritizing data excessively and adhere to the inherent characteristics of traditional opera art. Whether it is stylized movements in virtual scenes or algorithm-generated arias and librettos, all should always aim to convey emotions and meanings, striking a balance between technological innovation and artistic rules.

From the modern translation of opera stylizations via digital images, to the multi-dimensional expansion of audience reception paradigms through sensory technologies, and further to AI' s in-depth involvement in the creative system, technological innovation is reshaping the artistic essence and cultural identity of traditional opera films in the digital age. Future creation of traditional opera films will continuously explore the balance between technological rationality and artistic lyricism within the symbiotic relationship of human-machine collaboration.

5 CONCLUSION

Since the new century, digital technology has propelled traditional opera films to achieve crucial leaps and systematic innovations. It has successfully established a technological aesthetic system that integrates the core aesthetics of traditional opera with modern modes of expression, opening up brand-new horizons for creative practices.

However, technology is inherently a double-edged sword. For the future innovation of traditional opera films, on the basis of deepening the integration of art and technology, we must always adhere to the core principle of taking traditional aesthetics as the foundation and the essence of traditional opera as the core, and resolutely avoid the trap of employing technology merely for its own sake.

Meanwhile, we should actively explore diverse application scenarios for new technologies. While firmly safeguarding the cultural roots, we need to accurately meet the aesthetic demands of contemporary audiences and earnestly fulfill the contemporary mission of cultural inheritance and cross-cultural communication. Ultimately, this will realize the creative transformation and innovative development of traditional opera art, enabling traditional opera films to become an important carrier for conveying the spirit of Chinese aesthetics and core cultural values.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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