ingegneria sismica
International Journal of Earthquake Engineering
Anno XLIII - Num. 3 - 2026

Interactive Digital Technologies in Performing Arts: Exploring AI-Driven Creation and Co-Creation Mechanisms

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SUMMARY: *The use of artificial intelligence and interactive technologies has altered the very nature of the performing arts, introducing new approaches to performance-making, audience participation, and collaboration. This paper analyses AI-based processes' uses, advantages, and disadvantages in modern performance environments. We investigate how AI can enhance music, movement, playwriting, and stage and multimedia performances by extending the generative models, machine learning systems, and real-time interactive platforms. Various forms of engaging users in the co-production process, from input-output systems and generative tools to participatory interfaces, are discussed in the context of their computational structures and aesthetics. The review also highlights the new creative possibilities that AI opens up, its inclusiveness, and the latest types of artworks produced in collaboration with machines. At the same time, we discuss topical ethical issues regarding authorship, algorithmic bias, the agency of art, and technical platforms. Lastly, we discuss the prospects for the future comprised of advances in adaptive learning, interdisciplinary studies, and the guidelines for ethical uses of AI. This review, therefore, intertwines theories from arts, technology, and cultural studies to enhance the understanding of how AI is reshaping the epistemologies and practices of the performing arts in the digital age.*

KEYWORDS: *Artificial Intelligence in Performing Arts; Human-AI Co-Creation, Interactive Digital Technologies; Generative Creative Systems; Immersive Performance Environments*

1 Introduction

Since the 1990s, the rapid development of computer technology has led to various performance categories on interactive devices and the Internet. From early network cameras and CDs, to recent years' motion capture, motion sensing technology, and virtual reality technology, digital technology has completely changed the definition and mode of performance [1, 2]. Many creative ideas for works revolve around digital effects, such as enlargement, indentation, enhanced sound, high-resolution projection, and other creative elements that are not limited to performance landscapes or technical elements. The revolutionary role of computers has changed the previous distinctions and definitions of communication, scriptwriting, performance, science, design, drama, video, and performance. The combination of computer-based technology and performance is commonly referred to as digital performance. To some extent, new media performance and digital performance are interchangeable terms [3]. On the one hand, the development of digital performance is based on technological progress; On the other hand, digital performances also reflect many characteristics of mathematical literacy techniques. The non-hierarchical, unordered, and non-

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https://doi.org/10.65102/is20261071 Published: 10 June, 2026

material nature of digital technology itself provides new possibilities for the viewing and performance relationships, as well as the relationships between actors, narrative, media, and other elements in performances. Viewers break free from hierarchy and the passive posture in traditional viewing modes, becoming entities capable of achieving, changing, and even reshaping performances. Digital performances often emphasize interactivity and liveliness, distinguishing them from digital painting, digital cinema, and video art [4]. Of course, painting, film, and video are not mutually exclusive with digital performance. In fact, many artists have attempted to break through the boundaries of traditional digital art through new media techniques, constructing new narratives and expressions.

Digital technology not only provides new technological means for performance, but also helps to further break the inherent hierarchical system and viewing relationship of Cheng Kai. In digital performance, media is not only a carrier of information, but also highlights its own subjective value [5]. With the continuous evolution of digital technology, artists are constantly integrating new technologies into their performances, as well as challenging, deconstructing, and reshaping the interactivity in digital performances. The development history of digital art spans over half a century, and the corresponding works of art are numerous and unique, making it difficult to elaborate in detail within a limited space. According to the development history of digital performance, this paper selects three representative technologies in different periods: Internet, Virtual Reality (VR), and Artificial Intelligence (AI), analyzes their different interaction modes in interactive movies, VR performances, and AI devices through actual cases, and discusses the interactivity that technology may improve.

By its nature, the use of AI in performing arts is a multidisciplinary field that touches upon computer science, cognitive sciences, design, media, and culture. This review presents an overview of the existing literature and the trends in applying AI and interactive technologies in performing arts. It explains how AI can create and co-create, showcases AI applications in music, dance, and theatre, and looks at the potential and risks of these innovations in the digital cultural landscape. In this way, the paper aims to contribute to the growing literature on how technology transforms the aesthetic, ontological, and prospective dimensions of live and mediated performance.

2 Defining AI-Driven Creation and Co-Creation in the Arts

AI-driven creation in the performing arts involves using AI algorithms, especially ML, DL, and generative modeling, to automatically or semi-automatically design artistic content independently [6]. This may cover different areas and disciplines, such as music production, movement, dramatic text, scenography, or sound and visual art. Compared to other digital tools, AI systems possess a certain level of agency as they learn from data, model aesthetics, and create variable or potentially change outputs over time. Figure 1 illustrates the structural components of the AI-integrated performing ecosystem.

Co-creation, on the other hand, focuses on the dynamics of creativity where both parties are involved and engaged in the creative process [7]. In an AI context, co-creation refers to the participatory processes in which human artists, AI, and, at times, the live audience contribute towards the initial creation, alteration, or performance of art. It may happen in real-time during performance or via cyclical design processes where an individual works with another at a later point in time. However, co-creation relocates the creative process from an individual author to a collective of humans and non-humans with the help of computational technologies.

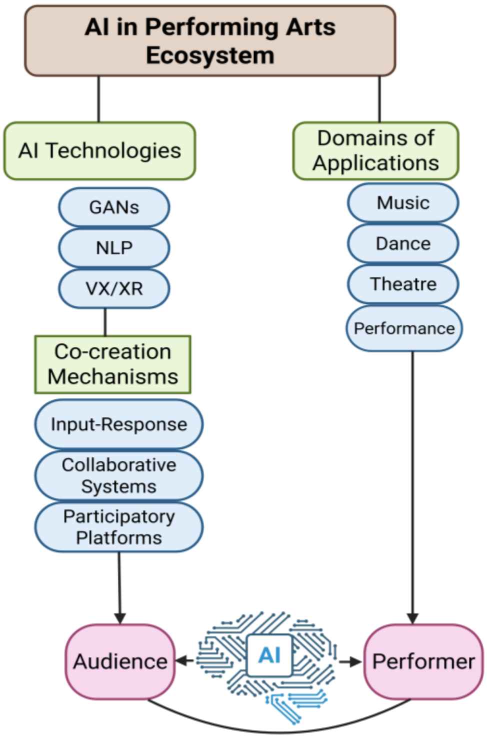

Figure 1: AI in performing Arts Ecosystem

From a technical perspective, several classes of AI models and platforms underpin this new creative paradigm:

Generative Adversarial Networks (GANs) [8]: GANs are generator and discriminator networks that work against each other to generate realistic synthetic data. In the artistic domain, GANs are applied to develop new art pieces, stylization stylize, design stage sets and costumes, and perform multimedia performances. For instance, performers have used models like StyleGAN to create avatars and transform faces and digital costumes in real time.

The core of GANs is to generate data through adversarial training of Generator (G) and Discriminator (D). The objective function can be expressed as:

$$\min_G \max_D V(D,G) = \mathrm{E}_{x\sim p_{\text{data}}(x)}[\log D(x)] + \mathrm{E}_{z\sim p_z(z)}[\log(1-D(G(z)))] \quad (1)$$

where, x is a real data sample that follows the real data distribution $p_{\text{data}}(x)$; z is a random noise vector that follows a prior distribution $p_z(z)$; D(x) is the discriminative probability of the discriminator on real data; G(z) is the fake data sample generated by the generator.

Recurrent Neural Networks (RNNs) and Transformer Architectures: RNNs and their more complex versions, such as LSTM networks, have been used in temporal data generation in music and sequential text synthesis. In particular, more recent models like GPT, BERT, and Music Transformer have delivered stronger performance in terms of fluency and stylistic variation across long sequences [9, 10]. These models allow an AI system to generate musical compositions or dialogues with the same emotional tone and narrative shape as a performance.

AI-Assisted Choreography Tools: The pioneer of VR technology, Jay Lanier, used dance as a metaphor for performativity and viewed interaction as an aspect of content. "Interaction is a concrete dialogue with a medium. This is how you dance with a computer. Vision is not important. What matters is the rhythm of interaction... It is not easy to feel this rhythm. This is a new form of art. From this argument, it can be extended to see that the dance piece VR_i, co created by Swedish choreographer Gilles Jobin and the founders of motion capture technology research center Artanim, Caecillia Charbonnier and Sylvain Chague, is a digital performance that returns to the original meaning of VR.

Interactive Installations and Performances: In the work, the video data stream is decomposed into a collection of pixels. If visitors want to manipulate the presented image, they can modify the corresponding parameters through the knobs on the panel. This is certainly the interaction between the audience and the performance subject (i.e. artificial intelligence), but to the uninformed audience, it seems as if the parameters they have adjusted themselves are directly applied to the image [11, 12]. They do not know that the work is not simply applying instructions directly to the video, but entrusting control to the TGAN algorithm. Visitors select and adjust specific parameters of pixels or images, which are passed to the TGAN algorithm. Subsequently, TGAN displays its simulated image on the screen based on the learned, remembered, and imitated image "features" that visitors may want to obtain. TGAN is an artificial intelligence algorithm for unsupervised machine learning that utilizes feedback from two competing sub neural networks. In "Meme," there is a neural network generator.

Moreover, the current frameworks for Human AI Interaction (HAII) in the arts are based on feedback loops, multi-modal input, and real-time interaction. Sometimes, these systems utilize affective computing to assess performers' or audiences' emotions to provide a more elaborate and empathetic co-creative process.

Therefore, creation and co-creation by AI mark a paradigm shift in performing arts from objects designed and authored to objects in flux, occurring, and interactive [13]. This process requires a radical overhaul of the positions of artistic practice, working methods, and aesthetic paradigms, which situate AI as an agent within the social creation of culture rather than as an instrument. Figure 2 shows the artificial intelligence driven creative process in performing arts.

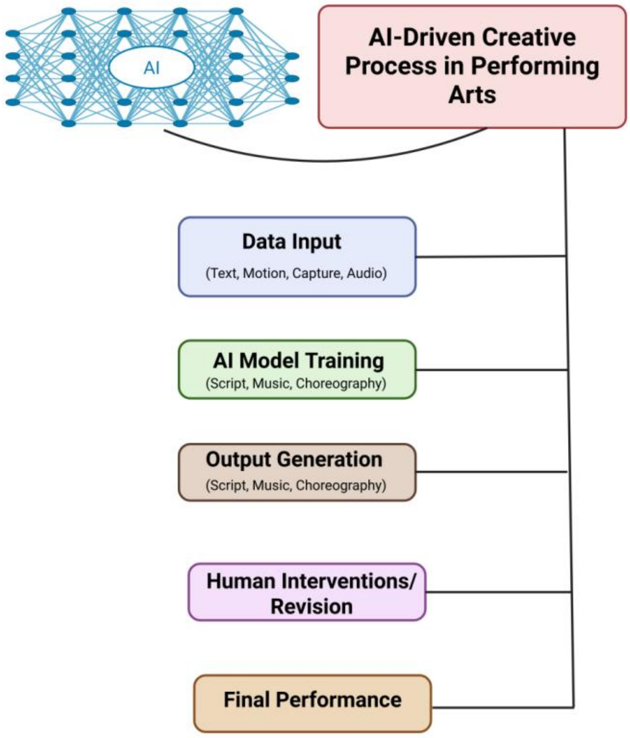

Figure 2: AI-Driven Creative Process in Performing Arts

3 Applications in Performing Arts

By integrating AI and interactive digital technologies in the performing arts, the performing arts have been reshaped in terms of performance practices. These technologies are creative assets and co-creative forces that can shape a space's structure, appearance, and performativity [14]. This section describes their uses within four main areas: music, dance, theatre, and live interactive performance. Table 1 shows an overview of artificial intelligence applications across art forms.

Table 1: Overview of AI applications across art forms

Art Form	AI Tools	Example Technologies	Use Cases
Music	LSTM, Transformer	MuseNet, Magenta	Composition, live accompaniment
Dance	CNN, MoCap	Move Mirror, StyleGAN	Choreography, gesture mapping
Theatre	NLP, GPT	GPT-4, Improbotics	Scriptwriting, live dialogue
XR	VR/AR, Unity	Infinite Drum Machine	Immersive environments

3.1 Music

The realm of computational musicology and algorithmic music composition has advanced significantly due to artificial intelligence. Current technologies like OpenAI’s MuseNet and Google’s Magenta use LSTM networks and Transformer-based models to analyze symbolic representations of music and generate new music based on the analyzed data [15, 16]. These tools can create many independent melodies at once, imitate the works of certain composers, and create harmonic harmonies and melodies in bigger pieces that are logically connected.

In real-time performance, AI is used as an accompanist or ensemble member. With the help of audio analysis and signal processing, AI systems can analyze the tempo, pitch, timbre, and dynamic contours of live instruments or voices and then respond with harmonically related and rhythmically aligned accompaniment. Two platforms are OMax, developed at IRCAM, and Impro-Visor, which incorporate probabilistic and symbolic models for real-time interaction.

Furthermore, there is AI-assisted compositional personalization, where audience, physiological data (such as heart rate), or other contextual metadata can be used to guide the generation of music. This erases the division between live and recorded sound, creating a new performance paradigm as real-time data feedback [17].

3.2 Dance and Choreography

AI in choreography involves the creation and enhancement of human movement by using models based on MoCap data. Modern deep learning tools such as convolutional neural networks for spatial feature extraction and long short-term memory networks for temporal modeling have made it possible to create systems that can learn, analyze, and generate dance movements [18]. Examples of available performative interfaces include projects such as Google's Move Mirror, which tracks user movement in real-time and maps them onto a database of choreographed dance moves.

Others are more advanced and are seen in professional and experimental dance performances. British choreographer Wayne McGregor worked with researchers at Google

Arts & Culture Lab to teach AI models how to study his collection of choreography pieces and create new dances [19]. These outputs were not replacements for human choreography but as stimuli that impacted the human choreographic process. This is a form of shared authorship where the machine initiates, and the human selects.

AI is also applied in the embodied interface where dancers employ motion capture technology to manipulate generative visuals, sounds, or environments (for example, using OpenPose) [20]. These interfaces allow a closed loop between body and digital space, enhancing the phenomenological aspect for the performer and spectator.

3.3 Theatre and Spoken Performance

Theatrical performance, in practice, has always been told through narrative, and AI interventions in this context have concerned natural language generation, affective computing, and interactive dramaturgy. Thanks to the latest developments of NLP, especially LLMs, such as GPT-4, AI can create context-based dialogues, switch between scenarios, and create realistic characters in real-time.

One of the most famous examples of this type of application is the project "AI: When a Robot Writes a Play" from the Czech Republic in 2021. In this case, the 125M GPT-2 was trained from scratch on a dataset of dramatic literature to generate a complete script of a play [21, 22]. As the text needed to be edited by a human to ensure it was coherent and would perform well, the final result demonstrated the possibilities and drawbacks of using AI for dramaturgy.

In interactive theatre, AI agents act as adaptive dramaturgs that adapt the performance to live cues such as audience emotions, facial expressions, or verbal gestures. Dialogue systems are also applied in training and development, particularly in acting and education, to facilitate role-playing. Occasionally, robotic performers or avatars are incorporated as free-standing or semi-free-standing characters, broadening the concept of the dramatic "company" to include artificial intelligence.

3.4 Immersive and Interactive Performance

Extended reality (XR), including virtual reality (VR), augmented reality (AR), and mixed reality (MR), have revolutionized immersive performance environments. These technologies allow performers and spectators to live in virtual environments in which interactivity is both verbal and gestural.

Solutions like The Infinite Drum Machine by Google Creative Lab employ unsupervised learning to categorize thousands of sound samples based on their perceptual similarities so that users can build rhythms interactively. In VR operas and digital dance performances, the audio-visual content of the performances changes in response to the user's movements, gaze, or physiological information, giving a real-time agency to the audience in shaping the performance [23].

Many works in XR are performative, meaning that AI systems generate scenography, lights, or narrative content according to predefined rules and live data streams. Using tools like Unity ML-Agents and Unreal Engine's Blueprint, developers can implement logic into a narrative structure that evolves depending on the participant's actions, providing a non-linear experience for the individual.

In this sense, the performance is a computational event in which the performer, system, and spectator are not clearly defined. Audience members might be involved in making aesthetic decisions or even become performers and participate in the show with AI performers as avatars.

3.5 Mechanisms of AI-Driven Co-Creation

Co-creative machine collaboration in the performing arts involves several interactive and computational interfaces that mediate between human performers or spectators and artificial intelligence [24]. They vary in interaction, self-organization, and time dependence, but all aim to create dynamic, adaptive, and context-sensitive art. Implementing these systems involves machine learning techniques in signal processing, human-computer interface, and integrating data from multiple modalities.

3.5.1 Input-Response Systems

Input-response systems are the most basic form of interaction with AI. In this paradigm, AI systems are built to identify live signals from their environment, like sound, gesture, face, or motion, and respond to them in real time by producing generative or adaptive actions. These systems typically utilize:

Computer vision for tracking body pose and motion (e.g., OpenPose, MediaPipe)

Audio signal processing to extract pitch, rhythm, timbre, or amplitude features

Affective computing to infer emotional states from facial microexpressions or vocal prosody.

The system's response may involve the creation of audio-visual components (music, light show, projections), narrative shifts, or even the physical movement of the robots. Such systems need low-latency data pipelines, real-time multi-modal processing, and generative models that can produce coherent artistic pieces within performance limitations. Input-response systems can be used in interactive installations, digital concerts, or AI improvisation [25].

3.5.2 Participatory Platforms

Audience involvement takes the co-creative model one step further by allowing users to engage with AI systems via interfaces—frequently in real time—and coauthor performance paths. These platforms utilize:

Web-based or mobile interfaces to collect audience input (e.g., choices, gestures, biometric signals)

Multiplayer XR environments, where users co-inhabit digital performance spaces

Sensor networks embedded in physical performance venues.

These inputs are processed by an AI system and adaptive performance content for the narrative progress, musical interludes, scenography, or avatars' actions. The core technologies are reinforcement learning, probabilistic modeling, and adaptive script engines, which make for non-linear emergent experiences based on collective or single viewers' behavior.

Regarding the application of reinforcement learning in participatory platforms, reinforcement learning updates strategies through state action reward state (SARSA) or Q-learning, with the core formula as follows:

$$Q(s_t,a_t) \leftarrow Q(s_t,a_t) + \alpha\left[r_{t+1} + \gamma \max_{a'} Q(s_{t+1},a') - Q(s_t,a_t)\right] \tag{2}$$

where, s_t is the current state; a_t is the current action; r_{t+1} is the reward obtained after executing the action; γ is discount factors; α is learning rate; $Q(s_t,a_t)$ is a state action value function, representing the expected cumulative reward for performing action α in state ε.

Participatory systems must support (i) **Scalable computational infrastructure** for handling multiple inputs, and (ii) **Robust user interface design** to ensure intuitive engagement, (iii) **Data privacy and ethical considerations**, especially when handling biometric or personal data.

These platforms exemplify **distributed authorship**, where the creative agency is dispersed among human performers, digital systems, and live audiences.

4 Technical Requirements

These AI-driven co-creation processes, as described, entail the following [26]:

Real-time processing units (e.g., GPU-accelerated inference engines)

Multi-modal data fusion techniques for synchronizing inputs from audio, visual, and haptic inputs

Interaction design that focuses on functionality, interactivity, and aesthetics of the human-computer interface

Cloud-based systems or edge computing to enable scalability in participatory contexts.

Additionally, these systems require constant tuning and readjusting to ensure accuracy, reactivity, and compliance with the creative vision. Figure 3 correlates the different mechanism in AI-Human Co-creation mechanisms.

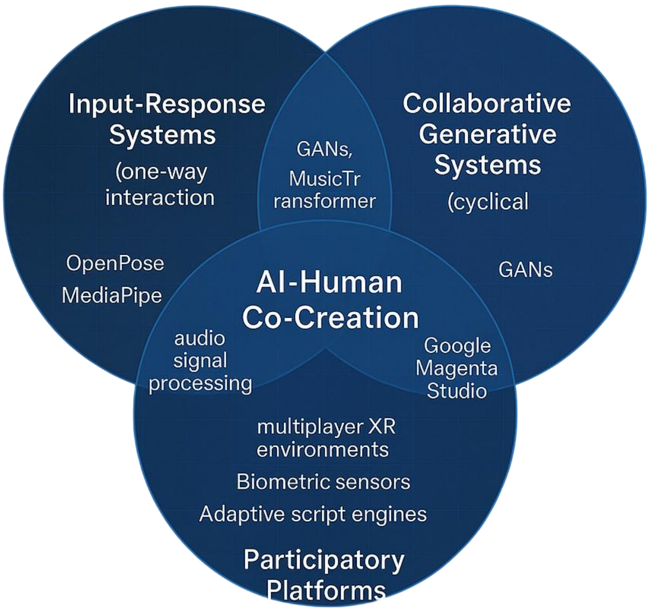

Figure 3: Mechanisms of AI-Human Co-Creation in Performing Arts

Consequently, the application of AI in the performing arts varies from reactive to fully symbiotic and participatory systems. They challenge the ideas of authorship, participation, and the presence of a performer, thus broadening the definition and potential of performance art.

5 Benefits and Opportunities

Artificial intelligence and interactive digital technology in performing arts have many positive effects on the field [27]. It ranges from the aesthetic to the epistemological and socio-cultural planes as emergent forms of creation, engagement, or art-making. In this section, the author describes the key benefits of AI-based systems and co-creation tools in the context of presentday performances.

5.1 Expanded Creative Boundaries

AI systems allow artists to explore creative domains that were previously impossible to consider due to the limitations of the mind, specialization, or style. Generative models, like GANs, VAEs, and Transformer-based architectures (GPT, Music Transformer) trained on large datasets can yield new rhythms, movements, visual forms, or text that would not be discovered through human creativeness.

For instance, it can blend different approaches to art (for example, Baroque and jazz or classical ballet and street dance), creating new forms that do not fit the traditional classifications. Furthermore, computers can consider a range of variants simultaneously and thus provide a high level of ideation flexibility, which is crucial for iterative design.

The ability to algorithmically combine, transform, and recontextualize art elements leads to the innovative search for works that take the artist to new directions beyond the well-worn practices and approaches.

5.2 Democratization of Art-Making

AI tools for creative purposes are now available with simple user interfaces, cloud environments, and open-source platforms (RunwayML, Magenta Studio, Touch Designer). These platforms facilitate artistic production for millions who are not professional musicians, dancers, or actors but can spend their leisure time performing arts for passion rather than pay [28].

AI lowers the technical skills required across many fields by automating complicated tasks such as generating harmony, capturing 3D motion synthesis, or creating real-time visual effects. This democratization makes the arts more accessible and inclusive, expands the talent base of creators, and allows marginalized voices to have a platform to present their ideas through computational media.

Furthermore, AI applications for educational settings include feedback and learning applications that can suggest exercises and introduce students to forms of practice that combine art, science, and technology.

5.3 Emergence of New Aesthetic Paradigms

The merging of AI and human work produces new aesthetic objects that cannot easily be categorized according to the traditional art genres. It also contains features such as:

Variability: every performance can be unique in different performances of the same piece, and the algorithms behind the performance challenge the idea of a stable artistic object.

Online collaboration: Art becomes an output of a collective interaction between the artists, viewers, and software.

The risk of ontological instability: AI systems may create content that cannot easily be classified, leading to new interpretive paradigms and critiques.

This could be an AI dance performance, a script generated by a neural network, and a sound environment that may vary in response to the spectators' brain activity. These works are process-based rather than product-based, collaborative rather than unidirectional, and non-linear rather than linear, which aligns with postmodern and posthumanist epistemologies [29].

These observations require reconsidering the concepts of intentionality, novelty, and originality concerning computational creativity.

Therefore, implementing artificial intelligence and interactive technologies in performing arts fosters creativity, collaboration, viewership, and arts progression. These benefits, nevertheless, prompt further questions regarding the ethical, cultural, and epistemological effects of such tools, which are discussed in the following section [30].

Table 2 presents an overview of twenty articles on the aesthetic engagement with and making of AI in theatre, dance, music, performance art, and installation.

Table 2: Overview of some recent studies

Year	Insights	Methods Used	Practical Implications	Findings
2024	AI-driven co-creation in performing arts with a focus on Korea.	Review of AI-human collaborations in performing arts across fields.	AI in performing arts leads to new forms of expression and interaction.	AI can collaborate in artistic creation, reshaping the arts industry.
2022	AI's role in intermedia theatre as a non-deterministic element.	Theoretical framework analyzing 13 AI-driven theatre works.	AI is a dynamic element in theatre that creates innovative performances.	AI's integration into theatre fosters dynamic, unpredictable performances.
2024	Text2Tradition, an AI system translating prompts into Thai classical dance.	Text and visual input processing for cross-cultural translation in dance.	Preserving and sharing traditional dance through AI-driven translation.	AI systems can bridge cultural gaps in art forms and preserve traditions.
2024	AI-driven animation techniques preserving Balinese dance movements.	Rotoscoping and motion capture techniques in AI-driven animation.	AI is a tool to preserve and represent traditional art forms accurately.	AI-driven animation tools ensure the accurate representation of cultural dance.
2024	Co-creation in dance improvisation, enhancing real-time collaboration.	Focus groups and analysis of dance students' real-time improvisation.	AI facilitates real-time collaboration and enhances dance creativity.	AI helps facilitate creative collaboration in real-time dance improvisation.
2024	AI in multimedia stage design with AR/VR for audience engagement.	Case studies of AI integration with AR/VR in theatre.	Transforming stage design and increasing engagement, particularly for disabled audiences.	AR/VR integration in theatre offers more accessible and immersive experiences.
2024	AI-generated content (AIGC) enhances creativity in stage art.	Qualitative interviews and surveys with stage art professionals and audiences.	AI-generated content expands creative possibilities while maintaining artistic integrity.	AIGC enhances creativity but requires balance to maintain artistic authenticity.
2022	Dream Painter project: AI generates art from spoken dreams.	AI-driven deep learning models for translating spoken input into art.	AI-driven art installations facilitate unique, audience-driven experiences.	Interactive AI-based art installations expand creative engagement with audiences.
2023	AI system allows real-time co-creation of music with gestures.	Real-time deep learning model interpreting gestures and speech for music.	Making music creation more accessible to non-musically trained individuals.	AI-driven music systems democratize music creation, even for non-musicians.
2022	The co-creation of music is centered around the Korean emotion 'Han.'	Surveys and expert interviews to assess AI-generated culturally resonant music.	AI aids in creating culturally relevant music while preserving cultural values.	AI-driven co-creation can preserve cultural identity through music creation.
2022	Interactive AI-driven performances in the metaverse enhancing audience participation.	Metaverse-based audience interaction using VR avatars and chat.	Breaking traditional audience-performer barriers with interactive VR experiences.	Metaverse-driven performances enable audience participation, transforming theatre.
2022	Integration of AI and new media technologies in theatre for audience interaction.	Exploration of AI and virtual reality in theatre for interactive experiences.	AI and new media technologies create immersive and interactive theatre.	AI and VR provide innovative ways to engage audiences in interactive performances.
2024	DanceGen is an AI tool that supports dance choreography through prototyping.	Diffusion-based AI models for generating dance sequences and prototyping.	AI tools enable choreographers to generate and prototype dance routines efficiently.	DanceGen supports choreographers by improving efficiency and creative possibilities.
2022	Probiotics and AI's role in absurdist theatre script co-writing.	AI in co-writing scripts for absurdist theatre through Improbotics.	AI assists in creative scriptwriting, offering new forms of theatre.	AI in theatre can redefine authorship and create new forms of absurdist theatre.
2017	AI in multi-modal learning to create dance sequences through auditory and visual data.	Multi-modal learning (auditory and visual) to generate dance sequences.	Multi-modal AI learning improves choreographic creativity and exploration.	Multi-modal learning with AI enables the generation of innovative and diverse dance sequences.
2010	AI system generates customizable dance sequences for choreographers.	Diffusion-based AI models for generating customizable dance sequences.	Generative AI tools enhance the customization of dance routines.	AI systems assist choreographers by offering more control and variation in dance creation.
2016	AI-driven virtual characters in interactive performances for audience engagement.	Creation of AI-powered virtual characters with machine learning for interaction.	AI characters enhance the audience's immersive experience in performances.	AI-generated virtual characters make performances more immersive and responsive.
2011	AI in AR/VR performances makes art more accessible to disabled audiences.	Case studies examining AI, AR, and VR technologies for accessible performances.	AR/VR with AI creates more inclusive and engaging performances for all audiences.	AI combined with AR/VR technologies creates more accessible and inclusive performances.
2024	AI's role in altering narrative structures in theatre through audience-driven choices.	AI systems create dynamic, audience-responsive theatre narratives.	AI enhances audience-driven narrative structures in theatre performances.	Audience-driven narrative choices in AI-driven theatre create dynamic and personalized experiences.
2024	AI-driven dynamic performance environments are responsive to audience behavior.	Real-time AI manipulation of performance environments for immersive experiences.	AI-responsive environments enhance immersion in live performances.	Real-time AI manipulation of performance elements enhances immersive live experiences.

6 Challenges and Ethical Considerations

The performing arts have been immersed in the creation and co-creation processes powered by AI, and these processes raise questions related to legal, philosophical, and technological implications as well as to culture. With AI systems becoming more involved in artistic practices or processes, ownership, control, morality, and support are now emergent concerns for theory and practice. This section will first describe the major and ethical issues related to AI in the performing arts.

6.1 Authorship and Ownership

One of the biggest controversies surrounding AI in art is the ownership and ownership rights of the generated artwork. Regarding creative works produced using artificial intelligence, such as generative neural networks or procedural content algorithms, the assumption of human authorship is rather questionable.

Some of the legal and ethical issues that remain unanswered include:

Who owns the rights to AI-generated content—the algorithm developer, the user who provided the input, or the AI system's trainer?

How is collaborative authorship between humans and machines recognized and quantified?

What legal status do co-created works occupy when AI outputs are unpredictable or emergent?

In some jurisdictions (e.g., the US Copyright Office and the UK IPO), current frameworks do not consider works created by machines as copyrightable. Thus, the forms of authorship that involve human intervention or selection, such as editorial decisions, are still legally ambiguous. These are especially important in a live context with AI integrated into the music, script, visuals, or choreography to perform during timed events.

6.2 Algorithmic Bias and Representational Ethics

Therefore, the decision-making and actions of artificial intelligence systems are influenced by the predisposed biases characteristic of large datasets. These biases may appear in the following ways:

Cultural bias, where datasets overrepresent Western or dominant aesthetic forms, marginalizing non-Western or subcultural artistic practices.

Gender and racial bias, where AI-generated avatars, voices, or scripts replicate stereotypes due to skewed training data.

Stylistic bias, where AI tools favour algorithmically 'learnable' patterns (e.g., tonal harmony, regular meter), sidelining avant-garde or improvisational modes.

These are technical issues, epistemological and aesthetic questions about AI performance's representation, interactivity, and ethical nature. Promoting inclusive datasets, bias checks, and cultural sensitivity is necessary to address these issues when designing AI for art.

6.3 Technical and Infrastructural Limitations

However, AI-integrated performance systems are still technically challenging for even the most modern hardware and software. Key challenges include:

Limited accessibility: Real-time AI has intense computational needs (often utilizing GPUs), making it challenging to implement in environments with limited computational resources.

Live feedback: Real-time generative responses must be in time with live performance cues, which is challenging, especially in multi-modal input and output.

Live environment: AI systems are used in live environments, which can be affected by noise, faulty sensors, or connectivity issues; backup protocols are required.

Thus, the creation and sustenance of AI for art require the input of various fields of study, including performance, computer science, interaction design, and data ethics. Such a requirement may challenge small-scale artists and institutions regarding costs and organization.

7 Conclusion

Artificial intelligence and other interactive digital technologies in the performing arts indicate a shift in the performing arts in both process and perception. This review has explored the diverse uses of AI in music, dance, theatre, and immersive environments and how machine learning, generative algorithms, and real-time data systems enable works created by AI alone and in collaboration with human artists.

Related to this shift is a reconceptualization of agency as the preserve of human performers and a system where intelligent systems can learn, evolve, and cooperate. From input-output structures to dialogical solutions, interactive feedback processes facilitate fluid and individualized interactions beyond the spectator-actor divide. New artistic hybrids emerge as people incorporate AI and art in their work, altering the traditional paradigms of originality, embodiment, and authorship.

There are outstanding questions as these new technologies extend creative potential, offer broader access to innovative tools, and encourage adaptive real-time performance. Issues of authorship, bias, and contemporary cultural relevance are important aspects that must be controlled by establishing appropriate AI frameworks and practices. Furthermore, real-time AI systems' technical and infrastructural requirements require interdisciplinary cooperation and sustainable development.

As for the future of AI in the performing arts, the present research suggests that the performing arts will likely be shaped not only by the continued development of AI technologies and the integration of such technologies into performances but also by critical analysis of the implications of such integration, the effective stewardship of AI technologies in the performing arts, and the formation of healthy working relationships between artists, technologists, and spectators. In this way, AI can exist not as a threat that snatches creativity away from human beings but as an enabler that enables creativity to evolve within a culture-sensitive and inclusive framework.

Funding

(1)The general project of the Beijing Municipal Education Commission's Social Science Plan "Strengthening the Construction of Beijing's Urban Cultural Space Based on the Resources of the Winter Olympics Culture.":SM202110012011

(2)This paper is a phased result of the Youth Project “Research on the Construction of New Spaces for Digital Cultural Tourism Performing Arts under New Trends in Arts Consumption”:25CWL17

(3)Special Project on “AI + Curriculum” Education and Teaching Reform of Beijing Institute of Fashion Technology “Exploration on Teaching Reform of the Course Cultural Resources Studies Based on the Concept of Digital Heritage Symbiosis”:AIKC-2458

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