Article

Research on the Evolution and Innovation of Performance Costumes from the Perspective of Mechanical Aesthetics

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Abstract: ***Background:*** The integration of technological innovation into performance costumes has been extensively explored, yet existing research mainly focuses on specific periods or individual technical cases. There is a lack of comprehensive exploration of mechanical elements in female concert costumes over time. Therefore, a systematic study explaining the evolution of performance costumes driven by mechanical aesthetics is urgently needed. ***Purpose:*** Using a ten - year cycle as a reference, this study traces the evolution path of mechanical aesthetics in performance costumes, analyzes its development logic, bridges the theoretical gap, and provides an analytical framework for design practices. ***Methods:*** Using literature analysis, case studies, historical evolution analysis, and interdisciplinary research methods, this paper examines the concert costumes of female singers from the 1980s to the 2020s. ***Results:*** Research shows that early mechanical aesthetics in costumes featured only simple decorative applications. As technology advanced, innovative combinations of function emerged, including the use of LED lighting devices. Currently, cutting - edge technologies drive high - level innovation, significantly enhancing the complexity and integration of mechanical elements. ***Conclusion:*** The mechanical aesthetics of performance costumes integrate technological design with cultural symbols. Understanding how these aesthetics have evolved can serve as a reference for costume innovation in the digital age. Future research could futrther explore this topic through cross - cultural comparisons and longitudinal studies.

Keywords: Mechanical aesthetics; Performance costumes; Historical evolution; Costume - technology fusion; Interdisciplinary design

1. Introduction

1.1 Research Background

Mechanical aesthetics and performance costumes have a scientific foundation that is rooted in humanity's relentless pursuit of beauty and technological development. Mechanical aesthetics emphasizes the close integration of form and function, which aligns with Corbusier's advocacy of combining architecture and industrialization (Lin, 2023). After the Second Industrial Revolution, the conflict between traditional craftsmanship and mechanical production, along with various social issues, gave birth to modernist design movements such as the German Manufacturing Union. This ultimately paved the way for the first generation of mechanical aesthetics (Lin, 2023), which emphasized logic, process, mechanical devices, and the combination of technology and structure (Wang, 2020). The second generation of mechanical aesthetics was proposed by the British School of Archigram in the late 1950s, which reinforces mobility and digital aesthetics through the "exoskeleton effect" of exposed structures. It builds supersensory spaces by combining a sense of technology and movement (Yang, 2018). Mechanical aesthetics is an aesthetic pursuit of the industrial era, which centers on the belief that machinery has a formal beauty similar to classical beauty, and that the construction and

appearance of machinery shows an untouched natural beauty because it conforms to functional and technological logic (Li, 2017).Futurist art manifests a mechanical aesthetic core by reconfiguring the experience of continuity of space-time and movement and profoundly influences the development of modern genres such as Cubism (Gu, 2017).

Performance costume design belongs to the category of costume design. However, due to the uniqueness of its design purpose and performance mode, it is essentially different from ordinary design projects in terms of theme creativity, design method, and technical approach (Xie, 2010). The power of machinery has not only changed the mode of production but also profoundly influenced the field of art and design. Nowadays, LED technology is widely used in the field of performance costumes, especially the dynamic light effect costumes for the leading performers in avant-garde concerts (Fu, 2022). By merging body language and lighting effects, a unique performance experience is created (Fujimoto et al., 2011). Additionally, integrating emotional interaction technology, etc., further enriches the design and expression of concert costumes (Xiong, 2024).

However, current research generally focuses on a specific period of time or centers on a single technological case, lacking a comprehensive examination of women's concert costumes over time from a longitudinal perspective. The role of mechanical aesthetics in the evolution and innovation of performance costumes is in urgent need of a systematic compilation and elaboration to address the research gap and build a more complete theoretical system. In addition, the current literature is limited to design or engineering perspectives, with little integration of interdisciplinary theories, resulting in a theoretical gap in the study of the "techno-cultural" inter-constructive relationship of mechanical aesthetics in the costumes of performances.

1.2 Research Purpose

Through the perspective of mechanical aesthetics, this study aims to systematically review the evolution of performance costumes from the 1980s to the 2020s and reveal how mechanical aesthetics has shaped and promoted the development of performance costumes by analyzing technological advances, material innovations, and the integration of art and technology. With the help of historical case studies, the study aims to provide a new perspective on the field of costume design, emphasize the central role of mechanical aesthetics in promoting the innovation of performance costumes, reveal the law of their design transformation, fill the theoretical gap between chronological analysis and interdisciplinary integration, and provide both theoretical support and practical guidance for the design practice of performance costume innovation in the future digital era.

1.3 Research Content

The combination of mechanical aesthetics and performance costumes not only reflects the perfect fusion of technology and art but also maps the continuous evolution of mankind's pursuit of aesthetics. The application of mechanical aesthetics in performance costumes has progressed from the roughness of steampunk to the refinement of cyberpunk and then to the seamless integration of modern technology and fashion. From the perspective of mechanical aesthetics theory, this study uses "technological determinism" to explore how technological advances have contributed to the evolution of performance costumes and how social and cultural changes have been reflected through costume design.

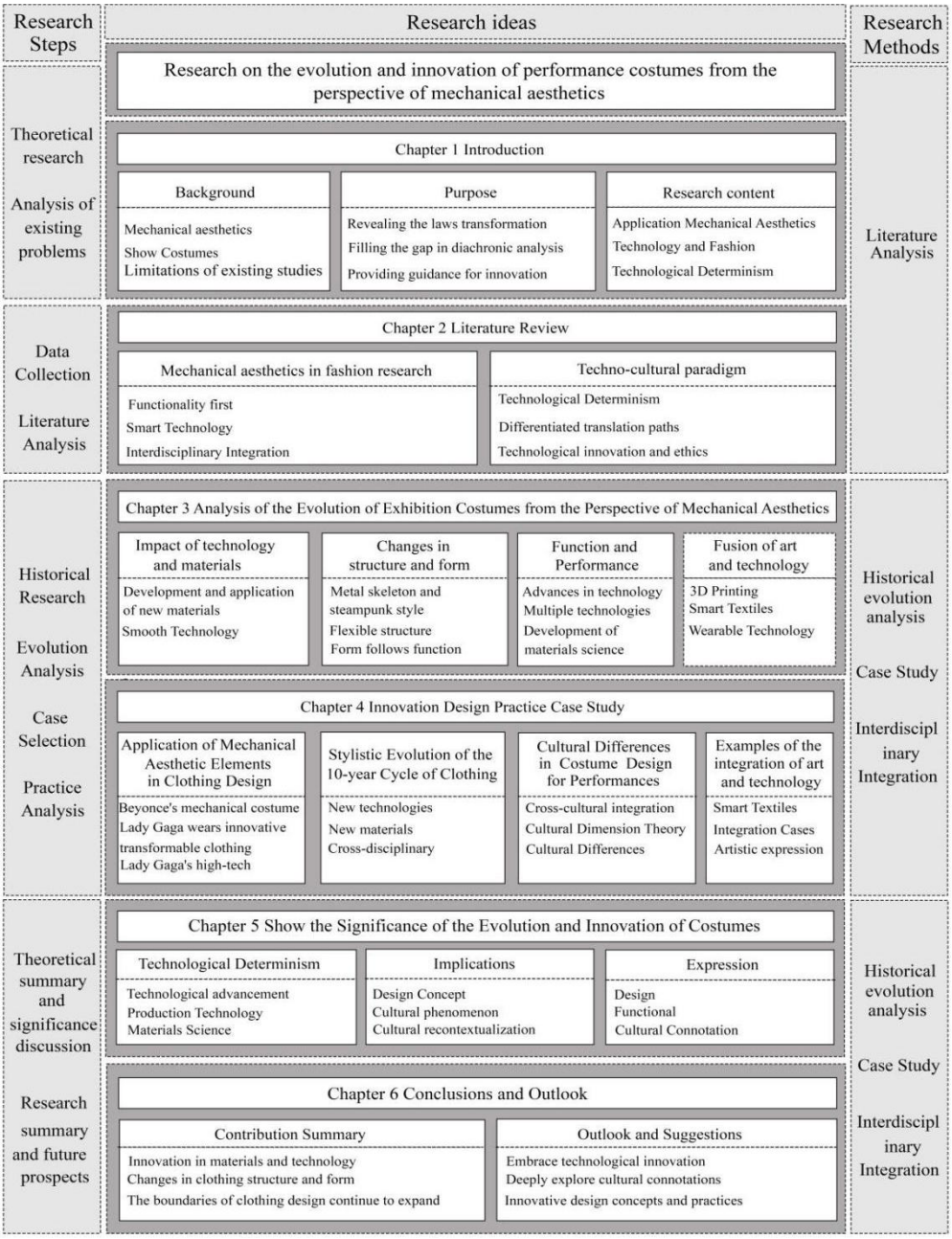

Figure 1: Frame diagram

1.4 Research Methods

In the process of exploring the historical evolution to innovative practices of mechanical aesthetics and performance costumes, this study employs a variety of research methods to ensure the comprehensiveness and depth of the study. First, an in-depth review of mechanical aesthetics in fashion studies, as well as academic papers on techno-cultural paradigms in recent years, was conducted through a literature review in order to establish a theoretical framework. Second, the case study method is used to select representative cases of innovative design practices to specifically analyze the application of mechanical aesthetic elements in apparel design. In addition, this study also employs the historical evolution analysis method to explore the cultural differences in costume design and its impact on the integration of artistic expression and technological innovation by comparing and analyzing the costume styles from the past ten years of exhibitions. Finally, through the perspective of interdisciplinary integration, the evolution and innovation of the performance costumes are comprehensively

evaluated by combining knowledge from the fields of mechanical engineering, material science, and art design, aiming to reveal how mechanical aesthetics has been manifested in the evolution of the costumes and its implications for the future.

2. Literature Review

2.1 Mechanical Aesthetics in Fashion Studies

The core of mechanical aesthetics in fashion research is to reconstruct the functional attributes and cultural semantics of clothing through the synergy of technical logic and artistic expression. Its development has gone through a paradigm shift from "function first" during the Industrial Revolution to "form-culture symbiosis" in the post-modern era. Early studies emphasized the efficiency and systematic characteristics of mechanical aesthetics, arguing that standardization and modular design are the basis for realizing the unity of function and form (Ye et al., 2019; Gao, 2014). With technological innovation, mechanical aesthetics are gradually integrated into clothing designs. This application is mainly reflected in the symbolic transformation of design elements, such as abstracting industrial symbols like gears and chains into cultural metaphors through deconstructive techniques and reshaping the visual language of modern clothing through geometrical lines and modular structures to give it the spiritual connotation of "unending life" (Shen et al., 2015; Wang, 2014).

In modern design, introducing smart technology further expands the boundaries of mechanical aesthetics and brings forth innovative design concepts by breaking the traditional model. 3D printing and artificial intelligence algorithms (AIGC) not only enable the dynamic expression of complex geometrical structures but also promote the design paradigm from "form first" to "algorithm first" (Cheng & Wang, 2022; Zhu, 2023). The 3D printing and artificial intelligence algorithm (AIGC) not only realizes the dynamic expression of complex geometric structures but also pushes the design paradigm from "form-first" to "algorithm-first" (Cheng & Wang, 2022; Zhu, 2023). Typical examples include the fusion of steampunk-style retro-mechanical elements with futuristic narratives, as well as smart interactive clothing that enhances stage narratives through sensor technology (Guo & Cai, 2017; Cheng & Wang, 2022). In addition, cross-disciplinary design inspirations, such as the combination of geometric form and functionality in jewelry design and perfume containers, demonstrate specific ways mechanical aesthetics can be applied in product design and provide new perspectives on apparel innovation (Yang, 2018).

The interdisciplinary fusion of mechanical aesthetics is not only limited to fashion design itself but also involves a variety of fields. Iris Van Herpen and Casey Curran collaborated on the APSARA Haute Couture dress, which features a butterfly sculpture and a corset design with wings that dynamically open and close via a micro-motor, achieving an innovative fusion of mechanical kinetic energy and dress aesthetics. This innovative practice not only enriches the concept of mechanical aesthetics but also provides a new perspective for the future development direction of performance costumes.

2.2 Technocultural Paradigm

The techno-cultural paradigm emphasizes that technology is not only a tool but also a force that shapes social structures and cultural practices. The technological paradigm shift is the core driving force behind the evolution of the cultural industry, which transforms the cultural forms by changing the underlying logic of technology (Fu & Zhao, 2024). The techno-cultural paradigm emphasizes that the practice of mechanical aesthetics needs to balance the logic of technology with cultural dynamism. Technological determinism believes that technological iteration is a unidirectional driving force for the evolution of performance costumes, for example, the innovation from metal materials to smart materials directly drives the functional transformation of

design (Zhu, 2023). Iris van Herpen's design breaks through the constraints of traditional costumes and combines modern technological means, such as 3D printing and magnetic technology, to create sculptural and futuristic costume works (Song, 2021). This fusion of technology and culture not only embodies the technological determinism in the techno-cultural paradigm but also demonstrates how performance costumes can be a medium for cultural re-contextualization. However, over-reliance on technological buildup (e.g., LED embedding) may lead to "technological spectacularization" and weaken cultural connotations (Zhou & Zhang, 2019). Therefore, cultural recontextualization becomes a key mechanism of techno-social interaction.

The study of mechanical aesthetics in Eastern contexts reveals differentiated paths of translation. For example, the metallic texture and geometric structure of modern Chinese paintings is a metaphor for the symbiotic relationship between technology and humanities (Gao, 2023), while the fusion of traditional patterns and innovative technology reflects the multifaceted possibilities of cross-cultural design (Lin, 2023). Such practices not only challenge Western-centrism but also reconfigure the semantics of mechanical symbols through traditional philosophical concepts such as "the beauty of the middle."

Technological innovation is the key to upgrading the functionality of mechanical aesthetics in performance costumes. For example, the minimalist style realizes the ultimate expression of mechanical aesthetics on "rational order" through algorithmic optimization (Ren, 2017). Analyzing the application of algorithms in different fields reveals how technological culture shapes cultural meaning through the interaction between technological practices and society (Fang, 2021). The integration of technological ethics further expands the social value of mechanical aesthetics. Although Artificial Intelligence Generative Design (AIGC) improves efficiency, data risks need to be avoided through ethical guidelines such as "privacy embedded in aesthetics" (Wang, 2023; Zhu, 2023). In addition, sustainable innovation pathways (e.g., modular, detachable design) respond to the need for global carbon neutrality by life cycle assessment. The core of the techno-cultural paradigm lies in maintaining the dynamic balance between technology-driven development and cultural critique through interdisciplinary integration (semiotics, communication, ecology) (Zhao, 2020; Fang, 2024).

The evolution and innovation of performance costumes are not only a direct result of technological advancement but also a product of interdisciplinary collaboration among designers, engineers, artists, and cultural scholars. This interdisciplinary practice of innovation not only promotes the development of performance costume design but also reflects the complexity of the interaction between technology and society in the techno-cultural paradigm.

Table 1: Summary of Literature Features

Research Direction	Reference	Trait
The Historical Evolution of Mechanical Aesthetics	The Journey of Machine Beauty. New Architecture, The Journey of Machine Beauty.	Function-first efficiency orientation with emphasis on standardization and modular design.
Modern technology integration and design transformation	Mechanical Aesthetics in Modern Dress Design. Changing Design Aesthetics in the Age of Artificial Intelligence.	3D Printing and AIGC Drive Dynamic Representation and Algorithm-First Design Transformation.
Interdisciplinary Innovative Practices (Cases)	An analysis of the influence of the "steampunk" style on clothing and its clothing characteristics. Mechanical aesthetics in jewelry.	Steampunk style, intelligent interactive costumes, and cross-disciplinary (engineering/art) fusion of exhibition costume innovations.

Differential Translation in an Oriental Context	On the Formal Expression and Cultural Meaning of Chinese Mechanical Aesthetics in Modern Painting. A comparative study on the reference of clothing design to mechanical appearance design.	The fusion of traditional patterns (Su embroidery) and intelligent technology reconstructs the symbiotic semantics of "science and technology - humanities."

3. Analysis of the Evolution of Exhibition Costumes from the Perspective of Mechanical Aesthetics

3.1 Impact of Technology and Materials

The advancement of technology has promoted the development and application of new materials, creating unprecedented possibilities in apparel design. The most representative example is the LED costumes that the Smooth Technology team has created for many singers' tours and stage performances. Cases such as the radio-controlled luminous jumpsuit Lady Gaga wore during her residency at the "Enigma + Jazz & Piano" concert in Las Vegas. The team collaborated with Paris Hilton's team to set up the lighting effects for the star's custom Marchesa gown and Hello Faerie wings for her performance of her album Infinite Icon at the Paladin Theatre in Hollywood, Los Angeles. In collaboration with Johnny Wujek on Katy Perry's Witness Tour, the customized radio-controlled LED bras displayed scrolling lyrics and rotated peppermint candies, hands, lips, and flowers. At the same time, the system worked seamlessly with the show's lighting controller. Smooth Technology created stunning gowns for Queen Jinkx Monsoon, who appeared in Season 7 of The RuPaul's Drag Queen Show. They customized the lighting and programming for her gown using 3D printing, laser-cut silk flames, blowers, mapped LEDs, and more. Demonstrating an innovative trend in the fusion of technology and aesthetics, the costumes push the boundaries, enhancing stage presence and visual impact.

In addition, the use of memory alloys not only gives clothing the characteristics of lightness and strength but also allows designers to create clothing structures with dynamic structural changes. British designer Hussein Chalayan uses shape memory alloy fibers built into clothing to change the shape of the clothing silhouette and achieve deformation of clothing. Joanna Berzowska and others studied a quilted leather corset called "Skwrath", which is made of stone leather and lined with blood-red silk. The head is designed with a wing-shaped sculptured collar that can cover the face and reveal the red lining after tearing. The abdominal structure comprises three interlocking leathers embroidered with shape memory alloy (SMA) wires. When activated by a customized electronic board, the wires will shrink and curl, showing the deep twill of red silk (Berzowska et al., 2005). Berzowska and Coelho (2005) studied a Kukkia dress, which has three dynamic flowers around the collar of the Kukkia dress, each of which opens and closes approximately every 15 seconds. The flower is made of felt and silk petals, which are hard and concealed, with nickel-titanium alloy wire sewn on the back. When heated, the alloy wire shrinks to close the petals; after cooling, the hardness of the felt is restored, and the flower reopens (Berzowska et al., 2005). Professor Wang Hongzhi's team at Donghua University developed a semi-solid gel as the lining material, using a transparent flexible conductive film as insulation and then putting it on a copper foil frame to optimize the conductive effect. Finally, a color-changing sheet with a thickness of A4 that can be folded freely is made. The color-changing sheet is combined with the traditional knitted cheongsam to present a series of technological cheongsams. Before the brake switch is activated, the decorative part of the cheongsam remains closed and fits the body shape. Once the switch is activated, the clothing slowly deforms locally, and the closed fan structure unfolds layer by layer under the action of the memory alloy, like a vibrant scene. Memory alloys bring rich styling changes to smart deformable clothing, showing vitality and dynamism that other materials cannot match, creating a

strong visual impact. The emergence of smart textiles provides a new dimension for the innovative practice of exhibition clothing.

3.2 Changes in Structure and Form

From a historical perspective, the structure of performance costumes has changed from static to dynamic, from simple to complex, from single to fusion, and from traditional to avant-garde.

In the early days of touring, costumes were more of a static display, with singers showing different images through their changing outfits. With the development of technology, costumes began to interact with stage effects, lighting, and other dynamic elements. In the 1980s, the initial show costumes were relatively simple, for example, Anita Baker in "The Rapture Tour" used only a basic set of clothing. Madonna, in "Who's That Girl World Tour," completed her tour with a few iconic outfits. In the 1990s and beyond, the variety of costumes increased significantly as stage technology and performance art advanced. For example, in "The Girlie Show (concert tour)," Madonna showed off intricate costumes designed by Dolce & Gabbana, including pinstriped suits and conical corsets. Whitney Houston has also introduced multiple costumes on several tours to enhance the visual impact of her performances. In the early days of touring, costumes focused on a single element, such as Madonna's Gaultier conical corset for the Blond Ambition World Tour. As designers and singers sought to innovate, multiple elements began to merge. For example, Madonna's "Sticky & Sweet Tour" featured a combination of styles, ranging from candy store-themed sweetness to more avant-garde designs, and many singers still retained a certain amount of tradition in their tours during the 1980s and 1990s, such as Cyndi Lauper and Whitney Houston. Their outfits showed their individuality while retaining the traditional aesthetics of pop music. In the 2000s and beyond, as the fashion industry grew more accepting of avant-garde designs, singers' tour outfits became bolder and edgier. Lady Gaga is known for her creative and visually striking outfits. During the Fame Ball Tour in 2009, she addressed her audience by wearing a dress made of plastic foam, and in 2014, after her final performance in Paris, she wore a "bright silver inflatable starfish costume" for a celebration party. At the Metropolitan Museum of Art Benefit Gala in New York City, Janelle Monae wore a Picasso-inspired costume showcasing Smooth Technology's mechanical design, movement, and programming, creating her iconic 2019 Met Gala red carpet look. The complexity of its construction and the innovative nature of its form not only pushed the boundaries of traditional dress but also demonstrated the potential of mechanical aesthetics in modern design.

In analyzing changes in structure and form, it is important to mention the classic design principle of "form follows function" in apparel design. This principle emphasizes that the design of costumes should first consider their functionality and practicality, while the form is a natural extension of function. This principle has been further expanded in showwear, where designers have used innovative structural designs to enhance the expressiveness and theatrical impact of the costumes. For example, Lady Gaga's performance during the 2020 VMA Video Music Awards epidemic wore customized masks that were both protective and responsive to sound, allowing her to sing live on stage without interference. This innovation in structure and form not only provided the audience with an unprecedented visual experience but also pushed the boundaries ofperformance costume design forward.

3.3 Changes in Function and Performance

The functionality of clothing is no longer limited to the traditional warmth and body covering, but expanded to more levels. By integrating miniaturized and flexible electronic components, smart clothing realizes information perception, emotional feedback and interactive functions, significantly expanding the functional boundaries of

traditional clothing. At the same time, with the help of phase change materials (PCM) and flexible electronics, smart clothing can automatically regulate the temperature, monitor the environment and physiological state, and dynamically adjust the performance, significantly improving the wearing comfort and sense of experience (Zhu & Zang, 2025). In terms of presentation, early in the 1980s clothing styles were dominated by simple models of dresses or suits, highlighting the singer's personal style. From the 1990s to the 2000s, the style became more diversified, incorporating elements such as rock and punk to emphasize individuality. From the 2000s to the 2010s, clothing was a combination of vintage and modern styles, and it was tightly integrated with stage performances in pursuit of shocking effects and customized personalities. From the 2010s to the 2020s, clothing styles are avant-garde and fashionable, breaking away from traditional aesthetics, adopting exaggerated silhouettes, strange materials, and surreal shapes, highly customized and incorporating technological elements, as well as focusing on the effects of social media communication, pursuing visual impact and topicality.

Designers utilize various technologies to create unprecedentedly complex structures and forms that are not only aesthetically pleasing but also dynamically respond to the wearer's movements, bringing the garment to life. Laura Pausini wore an aqua dress at the Inedito Tour, which glowed in time with the music, a customized version of the Aqua Dress from the 2012 CuteCircuit haute couture collection. In addition, the development of materials science has enabled clothing to have properties such as water-resistant, breathable, and self-cleaning. These functional improvements have undoubtedly enriched clothing's expressiveness, making it an interactive medium.

3.4 The Fusion of Art and Technology

With the rapid advancement of digital technology, innovations such as 3D printing, smart textiles, and wearable technology have a profound impact on the process of apparel design and production. For example, 3D printing technology allows designers to explore the structure and form of garments in an innovative manner, creating complex geometric shapes that would be impossible to achieve by traditional handcrafting by precisely controlling the deposition of materials. This technology not only increases design flexibility but also reduces the time from concept to finished product.

The integration of art and technology is also reflected in the application of smart textiles in the show's costumes. In her 2013 fashion show, Dutch designer Iris van Herpen showcased clothes made of magnetic materials. These clothes can transform shape in response to the magnetic fields, presenting a visual and technological feast for the audience. Beyoncé wore a 3D printed liquid metal skirt designed by Iris van Herpen in the 2023 "Renaissance World Tour." It uses thermosensitive color-changing materials and dynamic origami structures. Body temperature and movement trigger the flow of surface colors to simulate the texture of molten metal. Björk wore a biological fabric costume grown from 3D printed fungal mycelium in "Cornucopia" in 2019. When combined with a breathing sensor, the costume expands and contracts with the singer's breath frequency, simulating the metabolism of organic life. This innovation not only demonstrates the potential of technology in artistic expression but also prompts a rethinking of the function and aesthetics of traditional clothing.

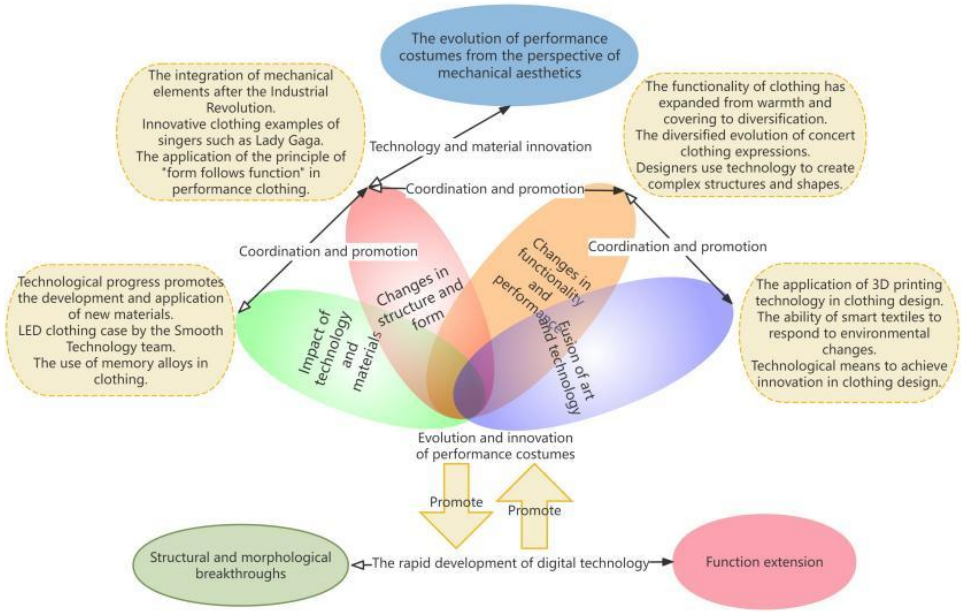

Figure 2: Analysis of the Evolutionary Path of Exhibition Costumes Driven by Mechanical Aesthetics

4. Innovation Design Practice Case Study

4.1 Application of Mechanical Aesthetic Elements in Clothing Design

The application of mechanical aesthetics in the design of performance costumes not only reflects the challenge of traditional aesthetics but also shows the perfect integration of modern technology and art. In recent years, performance costumes have incorporated high-tech interactive technologies, such as smart textiles, AR/VR, motion capture, and projection mapping. For example, Beyonce wore a mechanical costume in her concert, which combined motion capture and mechanical structure and was activated in real-time with hand gestures. In contrast, Lady Gaga wore an innovative deformable costume in "The Monster Ball Tour", which combined various materials to create a unique and adaptable performance costume. In addition, Lady Gaga's "The Born This Way Ball" tour featured high-tech costumes, with designer Perry Meek combining mechanical and electronic technology to help Gaga and her dancers move freely around the stage. Furthermore, for Lady Gaga's "Bad Romance," costume designer Nicola Formichetti created a mechanical shoulder armor with modular metal stitching and hydraulic lifting mechanisms to match the dance moves and create a sense of mechanical compression. For Björk's Utopia tour, she collaborated with the Dutch studio Iris van Herpen to create a biomechanical feather suit with a titanium 3D-printed wing skeleton and sensors embedded in the joints to control the amplitude of the feathers' opening and closing through gestures and a combination of birdsong and samplers to achieve a "mechanical" look. Zhang Shaohan at the 2023 "Fable" concert showcased silver-white hair color with cyber-style metal armor, a cold mechanical wind, and a fashionable sense of the future. Zhang Liangying used DevilBeauty's mechanical battle armor for her latest music video, "Green Light," which turns sexiness into a sharp blade, armoring women's bodies with armor to break through traditional constraints, thereby giving women more power and confidence. These examples show the possibility of "human-clothing symbiosis" empowered by science and technology, and at the same time, reconstruct the gender symbols with Zhang Liangying's Cyber Armor, giving the power to critique the clothing culture.

The complex and futuristic structure of these costumes fully embodies the essence of mechanical aesthetics. This cross-border fusion not only expands the visual boundaries of the stage but also uses mechanical rationality as a medium to redefine the aesthetic and spiritual core of future fashion.

4.2 Stylistic Evolution of the 10-year Cycle of Clothing

From the 1980s to the present, the ten-year cycle of clothing evolution has consistently served as a "living archive" of the spirit of the times, using fabric as a medium to transform social trends and technological revolutions into wearable visual symbols. Each ten-year cycle of the dresses on display deeply reflects the changes in social culture, technological advancement, and consumer preference, and each iteration of style maps out human self-expression.

The 1980s and 1990s were characterized by a core of dramatic symbols, the popularity of synthetic fibers, and enhanced reflective effects of stage lighting. Madonna's Jean Paul Gaultier-designed conical corset and the metal studs in the Blond Ambition tour reflected the rise of feminism by subverting gender expression. Meanwhile, the 1990s and 2000s saw the rise of airbrush prints, low-cost mass production, and the use of Velcro for quick changes. The performance costumes turned to avant-garde experimentation, where reflective materials, electronic components, and minimalism co-existed. Björk's mechanical feathers and the Spice Girls' revealing sports outfits, respectively, embodied the collision of science and technology and subculture through biotechnology and street culture. The 2000s to 2010s opened the era of high-tech convergence, marked by the rise of smart textiles, 3D printing, and interactive installations. LED flexible screen is used in clothing, such as Kylie Minogue's laser dress, thermoplastic and the use of polyurethane materials. Thermoplastic polyurethane (TPU) materials are driving the trend for transparent clothing. Clothing serves as a medium for visual spectacle and conceptual expression, with the 2010s and 2020s highlighting the connection between the virtual and the real through AR/VR projections and cybernetics. Beyoncé's golden armor during the Formation tour was equipped with motion capture sensors that activated stage lasers in real-time. From 2020 to the present, it focuses on sustainability and meta-cosmic narratives, integrating recycled materials, NFT digital clothing, and smart sensory fabrics. An example is Billie Eilish's Oversized Silicone Jacket from the Happier Than Ever tour, which uses genderless tailoring and eco-friendly silicone to address climate issues.

In the field of performance costumes, technological determinism is evident in how the invention of new materials and the application of new technologies have influenced new design trends. For example, in 1986, Madonna wore a black Trashy Lingerie corset and fishnet stockings while performing "Open Your Heart" as the opening song of her concert. In 1990, Madonna wore a gold conical corset designed by Jean Paul Gaultier, and in 2012, they collaborated again to revive the classic with an innovative twist, creating a conical corset with a rigid openwork structure. This change in style is not only a technological innovation but also a reflection of the deep integration of mechanical aesthetics in clothing design.

Figure 3: From left to right, Madonna wore corsets in 1986, 1990, and 2012
Source:https://en.wikipedia.org/wiki/Who%27s_That_Girl_World_Tour\https://www.lofficielusa.com/fashion/madonna-jean-paul-gautier-cone-bra-1990-history

In addition, the importance of interdisciplinary cooperation in the innovation of performance costumes should not be underestimated. The cross-innovation of mechanical aesthetics with technology and art has brought new perspectives and approaches to costume design. For example, the architectural style of Zaha Hadid, characterized by curved shape, sharp angle structure, fluid shape abstract space, and other elements of the reconstruction of the dress modeling, has influenced the structure and form of garment design. This interdisciplinary fusion not only enriches the visual language of the costumes but also promotes the cyclical evolution of the show's costume styles.

4.3 Cultural Diversity in Exhibition Costume Design

When exploring cultural differences in exhibition costume design, it is important to mention how mechanical aesthetics can be reinterpreted and applied in different cultural contexts. Japanese designer Rei Kawakubo's Comme des Garçons label often fuses Eastern minimalism with Western avant-garde design to create a unique style of dress. Her designs not only reflect the Zen aesthetics of Japanese culture but also challenge and dialogue with the Western fashion world. Through this cross-cultural fusion, the performance costume design not only demonstrates innovation in mechanical aesthetics but also serves as a bridge of communication and understanding between different cultures.

Dutch social psychologist Hofstede's theory of cultural dimensions summarizes cultural differences into multiple dimensions such as power distance, individualism and collectivism, masculinity and femininity. For example, in an individualistic culture, performance costume design tends to focus more on expressing the designer's personal style and creative freedom, while in a collectivistic culture, costume design may emphasize more on harmony and unity with the social group. This cultural difference is reflected in the design of exhibition costumes, which affects the appearance and function of the costumes and also reflects different social values and aesthetic orientations.

In the interdisciplinary integration of mechanical aesthetics and exhibition costumes, cultural differences also play a key role. Taking the cross-innovation between technology and art as an example, designers from different cultures will utilize their own unique perspectives and resources to incorporate elements of mechanical aesthetics into costume design in different ways. For example, in the trailer for Lady Gaga's "The Monster Ball Tour," Gaga is wearing her iconic pyrotechnic bra, emitting sparks. On the one hand, this innovation enriches the expression of mechanical aesthetics. On the other hand, it reflects that cultural differences drive the diverse interpretations of mechanical aesthetics in clothing, at the same time, promotes mutual understanding and respect among different cultures.

Table 2: Cultural diversity in different countries

Nations	Cultural dimension characteristics	Mechanical aesthetics application features	Typical case	Case Photos
Japan	Collectivism, long-term orientation.	Focusing on the fusion of function and form, mechanical deconstructionism under Zen aesthetics.	Geometric modular design by Rei Kawakubo (Comme des Garçons).	

United States	Individualistic, highly innovation-oriented.	Emphasizes personal narrative with sensory impact and pioneering experimental crossover.	Lady Gaga's "pyrotechnic bra" enhances the drama of the stage through mechanical devices.	
Netherlands	Highly feminized, care-oriented.	Ecological ethics are integrated into technical design, dynamic sculptural sensibility and ergonomics.	Iris van Herpen 3D printed dress.	

4.4 A Case of Fusion of Artistic Expression and Technological Innovation

In exploring the innovative practices of mechanical aesthetics and performance costumes, cases of fusion between artistic expression and technological innovation provide valuable research materials. The emergence of smart textiles has not only changed the physical form of dress but also expanded the boundaries of artistic expression. At Paris Fashion Week 2023, Coperni presented an innovative design using inkjet technology to print garments on-site. Supermodel Bella Hadid wore a white matte dress that was formed by spraying directly onto the human body with an air gun, which dried quickly. Later, a seamstress came onstage and fine-tuned and cut the dress again, highlighting the versatility and sustainability of the fabric material. In addition to improving the accuracy of design, it also shortens the cycle from design to finished product. Technological innovation is profoundly affecting the design and production process of the performance costumes.

Figure 4: Bella Hadid in Coperni's Inkjet Technology Live Printed Outfits
Source:https://www.dezeen.com/2022/10/04/spray-on-dress-paris-fashion-coperni-bella-hadid/

5. Show the Significance of the Evolution and Innovation of Costumes

5.1 Technological Determinism in the Evolution of Dress in the Context of Mechanical Aesthetics

Technological determinism recognizes that technological progress is a major force for social change and cultural development. This is particularly evident in the field of clothing. The invention and popularization of the sewing machine in the late 19th and early 20th centuries greatly improved the efficiency of clothing production, making complex decorative and structural designs possible, thus giving rise to the clothing styles of the Art Nouveau movement. During this period, the lines of clothing became more fluid and the decorative elements more elaborate, reflecting the profound influence of mechanical aesthetics on clothing forms. In the 21st century, with the development and application of digital technology, the design and production of performance costumes have once again undergone revolutionary changes. For example, Taylor Swift's 1989 World Tour gown and 12 dancers were embedded with LEDs, and

each costume was individually controlled wirelessly via DMX, using all custom-designed software and hardware. It can be seen that the clothing has not only broken through the boundaries of traditional clothing visually, but also achieved unprecedented possibilities in terms of functionality. It has further realized the integration of mechanical aesthetics into clothing design through technical means, thus promoting the evolution of exhibition clothing.

Particularly noteworthy is the application of technological determinism in the evolution of exhibition clothing, which is reflected not only in the innovation of production technology, but also in the progress of material science. Studies have shown that the invention of polyurethane elastic fiber (Spandex) allows clothing to fit the body better, providing designers with greater creative freedom. The widespread use of this material has made the structure and form of clothing more diverse, and has also promoted the popularity of tight clothing.

The Evolution of Dress in the Perspective of Mechanical AestheticsTechnological determinism emphasizes the importance of technological advancement in promoting the form, function, and cultural expression of dress. Throughout history, every technological leap has been accompanied by changes and innovations in clothing styles. For this reason, the development of future exhibition costumes still needs to pay close attention to the latest technological advances to create more striking costumes guided by mechanical aesthetics.

5.2 Insights into the Evolution of Exhibition Costumes and Cultural Recontextualization

Mechanical aesthetics is not just a design concept, it is also a cultural phenomenon that reflects mankind's continuous exploration of the integration of technology and art. The Industrial Revolution from the late 19th century to the early 20th century gave rise to not only new methods of production, but also new aesthetic concepts. Costume designers began to utilize new materials such as rubber and wire to create unprecedented forms of dress. In the social and cultural context of the time, these costumes, while achieving the benchmark of technological advancement, further realized the vision of the future and the worship of mechanical power. With the steady advancement of technology, the design and production of the costumes have gradually incorporated more high-tech elements. At the 2010 Met Gala, Katy Perry wore a dress designed by CuteCircuit. The dress was embedded with LED lights that changed color and glowed at night, making it the first wearable technology garment to debut on the red carpet.

Figure 5: Katy Perry's Color-Changing Glow Dress at the 2010 Met Gala
Source:https://www.gettyimages.co.jp/%E5%86%99%E7%9C%9F/katy-perry-met-gala-2010

In addition, the evolution of exhibition costumes also reflects the trend of cultural recontextualization. With the deepening of globalization and increasingly frequent exchanges between different cultures, the design of costumes for performances has begun to integrate multicultural elements. This cross-cultural integration not only

greatly enriches the visual language of clothing, but also promotes mutual understanding and respect between different cultures at a deeper level.

5.3 Mechanical Aesthetic Elements in the Evolution of Clothing

The evolution of mechanical aesthetics in performance costumes reflects a threefold variation of technology, art, and culture, gradually evolving from symbolic decoration to wearable technology art installations. Its forms of expression are constantly changing with technological progress and artistic trends. Early explorations used leather clothing inlaid with metal rivets and gear decorations, paired with exaggerated metal shoulder armor and mechanical masks, to shape the image of "mech warriors" through rough industrial symbols, strengthening the rebelliousness and power of rock music. Lady Gaga's 2014 tour "ARTPOP" has movable structures and interactive experiments, and the "mechanical octopus skirt" created by Dutch designer Bart Hess, with 6 hydraulically driven metal tentacles swinging with the dance, simulating the symbiosis of organisms and machines, and realizing the dynamic autonomous movement of stage costumes. Then there is the mechanical honeycomb costume in Beyoncé's 2023 "Renaissance" tour. The 3D-printed honeycomb metal skeleton fits the body curve, and the joints use memory alloy hinges, which open and close like a living shell with dance movements. Designers can directly transform complex mechanical structures into components of clothing. The Shenzhen stop of Jolin Tsai's Ugly Beauty Finale 2024 World Tour is a strong testament to this, with Jolin Tsai opening the show with a suit of golden armor and a golden circle on her head. This innovative interdisciplinary practice pushes the boundaries of costume design while reflecting the profound influence of mechanical aesthetics in the evolution of dress.

Figure 6: The golden armor Jolin Tsai wore on her Ugly Beauty Finale 2024 World Tour stop in Shenzhen
Source:https://news.qq.com/rain/a/20240407A02V7100

6. Conclusions and Outlook

6.1 Summary of the Contribution of Mechanical Aesthetics to the Evolution and Innovation of Exhibition Costumes

Mechanical aesthetics, as an innovative force in costume design, has contributed to the evolution and innovation of costumes in many ways. Drawing inspiration from history, mechanical aesthetics has contributed to innovations in materials and technology, and, by coincidence, to changes in the structure and form of clothing. "Technological determinism" considers technological progress as the main force driving social change. In the field of exhibition costumes, the application of mechanical aesthetics is a vivid embodiment of technological determinism, which promotes the continuous expansion of the boundaries of costume design through continuous technological innovation. Fashion is the combination of art and technology. Applying mechanical aesthetics in performance costumes is a perfect interpretation of this concept.

6.2 Prospects and Suggestions for Costume Design for Future Shows

The ongoing advancement of science and technology, along with the growing cultural diversity, presents unprecedented opportunities for innovation in performance costume design. The combination of mechanical aesthetics, as an important branch in the design field, and performance costumes indicates that future costume design will increasingly emphasize the integration of technology and art. In addition, the development of smart textiles will make costumes not only decorative in appearance but also an intelligent interface for interaction with the wearer. In terms of interdisciplinary integration, the cooperation between designers, engineers, and artists will become crucial, and the performance costumes they create together will be able to better express the spirit of the times and cultural values. The future design of performance costumes should actively embrace technological innovation while digging deeply into cultural connotations. This approach will lead the fashion trend with innovative design concepts and practices and show the infinite possibilities of mechanical aesthetics in exhibition costumes.

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