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Research on the Application of Generative Artificial Intelligence in Sustainable Fashion Design Models from the Perspective of Design Studies

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Abstract

With the remarkable advancements in deep learning and large language model technologies, generative artificial intelligence (Generative AI) has, in recent years, been increasingly applied in the fashion creative design industry. It has become a key driver for the intelligent transformation of fashion design processes and the innovation of design paradigms. At the same time, the global fashion industry is facing the dual challenges of severe overproduction and a fundamental shift in consumer awareness. This study, grounded in the perspective of design studies, adopts literature analysis and case study methodologies to systematically review the current development, application, and technological evolution of generative AI in fashion design. It further explores the necessity of AI-driven sustainable fashion design development and logical inquiry within the design discipline. Drawing upon the "Five-Dimensional Integration" (H-T-O-S-M) theoretical model, the research provides an in-depth analysis of the innovative pathways through which AI empowers sustainable fashion design, focusing on five dimensions: Human (H), Task (T), Objects (O), Space (S), and Mirror (M).The findings indicate that generative AI exhibits significant potential in promoting the green transformation of the fashion industry, particularly in areas such as pattern generation aligned with sustainable design principles, automatic optimization of garment structures to achieve zero-waste objectives, and material process simulation with emotional engagement. This study offers valuable theoretical references and insights for the application of artificial intelligence in sustainable fashion design from a design studies perspective and contributes to the further exploration and practical advancement of new paradigms in sustainable fashion design.

Keywords

Literature Analysis, Generative Artificial Intelligence Technology, Sustainable Fashion Design Models, New Paradigms of Human-Computer Interaction, Design Efficiency

1. Research Background

In the contemporary era, the rapid development of a new generation of generative AI technologies, exemplified by ChatGPT and Midjourney, has brought disruptive transformations across a wide range of industries. AI-assisted design, leveraging artificial intelligence algorithms for text generation and image recognition, has made it possible to create highly realistic images, videos, and audio content, driving groundbreaking innovation within the fashion creativity and design sector.

Meanwhile, as the global fashion industry continues to expand rapidly, clothing manufacturing and consumption have become major contributors to environmental pollution and resource depletion. It is projected that global fiber production will reach a historic peak of approximately 107 million tons by 2025. The marketing strategy of "fast fashion" continuously stimulates consumer purchasing desires, resulting in vast amounts of clothing being discarded before they are fully utilized, thereby further intensifying the ecological burden.

China has committed to achieving peak carbon emissions by 2030 and carbon neutrality by 2060. As a vital component of both the economy and culture, the fashion industry now stands at a critical crossroads, where the demands of technological transformation and sustainable development are deeply intertwined. The integration of technology and design not only enhances industrial efficiency and environmental performance but also urges designers to reexamine the relationships between humans and nature, as well as between technology and society. As Professor Lu Xiaobo of the Academy of Arts & Design at Tsinghua University noted (2023), the future advancement of design innovation and the development of the design discipline increasingly require broader and deeper interdisciplinary collaboration.

The academic community has also extensively explored whether generative AI can effectively support and integrate into sustainable fashion design. These discussions encompass a wide array of application areas, including the digitization of design thinking, low-carbon and waste-reducing production processes, sustainable fashion market analysis, the dissemination of sustainability concepts, the digital and intelligent preservation of traditional culture, and emotionally engaging design. Relevant generative AI technologies include Generative Adversarial Networks (GANs), deep machine learning and data mining, Natural Language Processing (NLP), digital technologies based on Augmented Reality (AR) and Virtual Reality (VR), and computer vision.

However, most of the existing industry applications remain focused on automating traditional garment design workflows and innovating linear human-computer interaction scenarios. The current state of academic research remains fragmented and has yet to provide the industry with comprehensive and robust theoretical support.

2. Literature Review

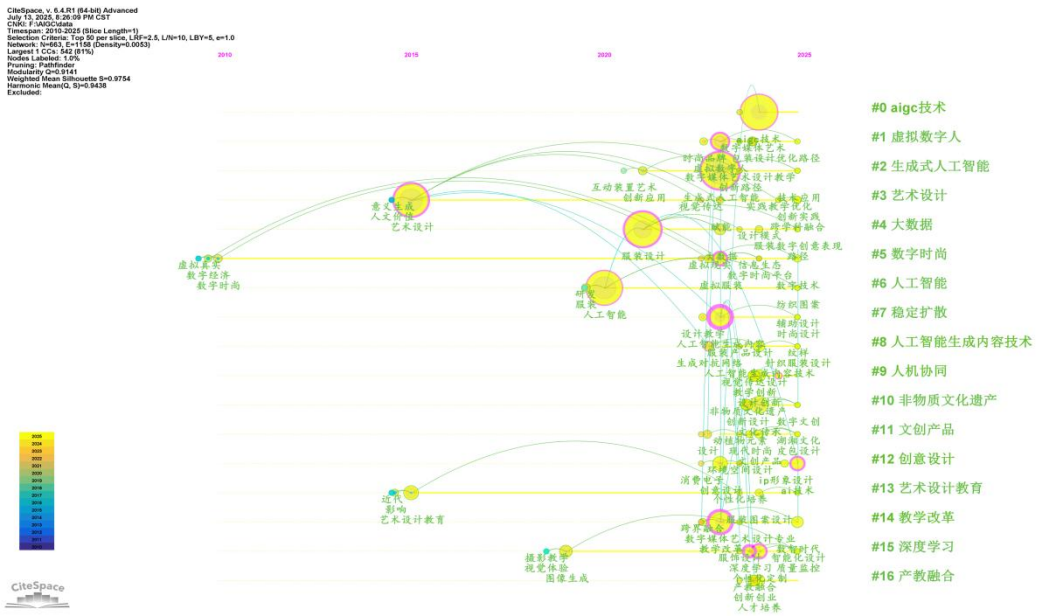
2.1 Analysis of Research Hotspots in the Application of Generative AI Technology in Fashion Design

To systematically and effectively collect literature on the application of AI-assisted design in the fashion design field, this study selected both Chinese and English databases as sources for bibliometric analysis.

In the China National Knowledge Infrastructure (CNKI) database, the search was conducted using subject terms such as "人工智能辅助设计" (AI-assisted design), "AI 辅助设计" (AI-assisted design), "人工智能技术" (artificial intelligence technology), "AIGC," or "虚拟数字" (virtual digital), in combination with keywords like "时装" (fashion), "时尚设计" (fashion design), "纺织品" (textiles), or "创意" (creativity). This yielded an initial collection of 480 Chinese articles.

In the Web of Science Core Collection database, the search terms included "Artificial Intelligence," "AI-Assisted Design," "Digital," or "Computational," combined with "fashion," "clothing," "garment," "Sustainable Fashion," or "Creative Industries." The search was limited to articles and reviews, resulting in an initial retrieval of 1,256 English publications.

To ensure the quality of the included literature, each article was individually screened based on its title, abstract, keywords, and core arguments. Non-academic materials such as prefaces, book reviews, news reports, and articles unrelated to AI-assisted design in the fashion domain were excluded. Ultimately, 356 valid Chinese articles and 489 valid English articles were selected for further analysis.



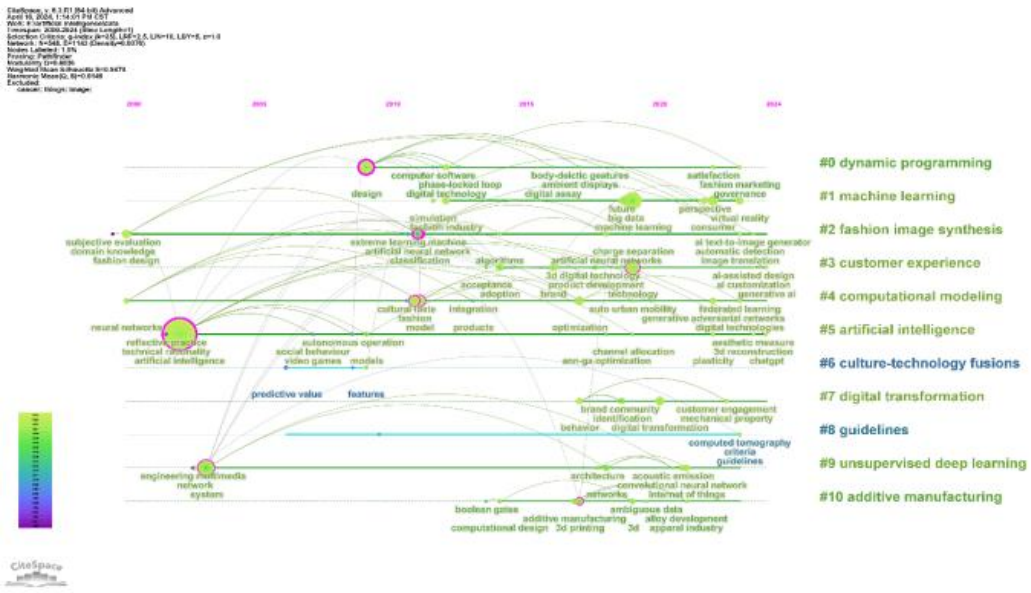


Figure 1. Timeline Analysis of Keywords Related to AI-Assisted Design in the Fashion Field

Figure 1 presents a timeline mapping of research keywords related to AI-assisted design in the fashion field. By examining the year when each keyword first appeared within its respective cluster and observing its subsequent evolution, we can analyze the developmental trends of domain knowledge over time. As shown in Figures 2 and 3, early research hotspots focused on keywords such as "intelligent clothing design," "virtual garment templates," "computer-aided design and garment manufacturing," "neural networks," "technical rationality," and "artificial intelligence."

Subsequently, keywords such as "machine learning," "digital fashion economy," "smart clothing," "digital virtual imaging," "simulation of the fashion industry," "algorithms," and "fashion image synthesis" began to emerge. More recently, the field has seen the rise of keywords and clusters such as "human-machine co-creation," "generative artificial intelligence technology (AIGC)," "deep learning," "AI-assisted design," "digital marketing," "harmonious symbiosis," "image recognition," "smart manufacturing," "interactive," "digital models," and "AI customization."

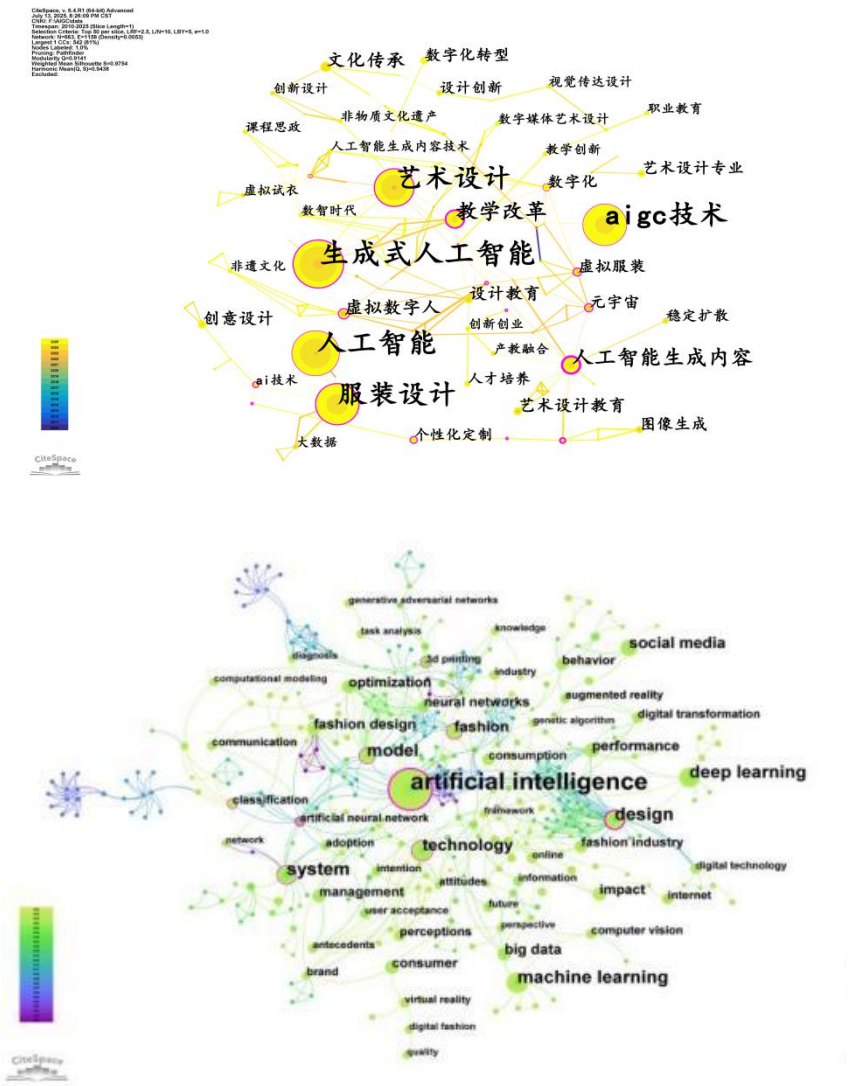


Figure 2. Cluster Analysis of Keywords Related to AI-Assisted Design in the Fashion Field

A comprehensive review of the keyword clusters from both Chinese and English sources indicates that current research on AI-assisted design in the fashion field primarily concentrates on four key areas:The development and application of AI technologies (e.g., #4 computational modeling, #6 mathematical models, #0 dynamic programming, #2 interactive genetic algorithm)，High-efficiency, automated innovative design (e.g., #10 conceptual design, #5 digital fashion, #9 garment design, #1 art design)，Intelligent generation powered by generative AI (e.g., #2 generative artificial intelligence, #11 AIGC technology, #2 fashion image synthesis)，Revolutionary transformation toward personalized consumer demands and human-machine collaborative design models (e.g., #12 interactive, #3 customer experience)，Meanwhile, the research increasingly focuses on the paradigm shifts and future development of AI applications across other creative industry clusters (e.g., #13 creative industries), with cross-disciplinary integration offering even greater possibilities for AI-assisted fashion design..

3. Current Research Status of Generative AI Applications in Fashion Design

A comprehensive review of the literature reveals that although numerous studies have investigated the application of AI in fashion design, there remains a significant shortage of research that systematically consolidates these advancements and recent outcomes to provide clear guidance and integrated insights for the fashion design industry. With the rapid progression of artificial intelligence, AI is no longer merely regarded as a technical tool but is gradually evolving into an "intelligent collaborator" within the fashion design process. Based on the earlier analysis of domain-specific keywords, combined with an in-depth review of the core content and research directions of 844 Chinese and English publications, this study identifies that current research on the application of generative AI in fashion design primarily focuses on three key areas: the exploration of autonomous fashion design under specific application scenarios, the intelligent integration and assistance throughout various stages of the design process, and the development of human-computer co-creation models for sustainable fashion design. These directions are grounded in both the technological principles of artificial intelligence and the design philosophies of sustainable development, reflecting the evolving synergy between AI and the future of the fashion industry.

3.1 Exploration of Autonomous Fashion Design in Specific Application Scenarios

In the fashion industry, when addressing clothing design scenarios that involve specific cultural attributes or personalized customization needs, the application of generative AI technology is no longer merely a tool for improving efficiency—it sometimes disrupts and redefines the industry's traditional understanding of established workflows. For instance, generative AI facilitates the digital translation of intangible cultural heritage garments, intelligent customization for users with special body types, and the provision of emotionally enriched design services for clothing intended for specific occasions. Research in this area often focuses on the design logic and cultural demands of particular garment categories, emphasizing the deep integration of technology and design within specific cultural and application contexts, thereby advancing the precise and effective implementation of AI tools.

For example, Yu Peng and Zhang Yi (2024) applied the Stable Diffusion model to generate fashion content featuring the distinctive characteristics of Miao ethnic clothing. Their study introduced deep learning into the modernization process of intangible cultural heritage garments, aiming to promote the ready-to-wear, diversified, and popularized development of ethnic apparel through digital innovation. Similarly, Hong Yan (2018) proposed a personalized fashion design support system that effectively addresses the automatic generation of customized garment styles and patterns for individuals with special body types, while also ensuring seamless integration with existing intelligent manufacturing platforms. Wedding and ceremonial attire, which has always been a highly personalized clothing category with strong emotional significance, is another area of focus. Wang Xinzi, Wang Jingwen, and Xing Le (2021) selected wedding dresses—garments with distinctive structural forms and specific wearing contexts—as their research subject, focusing on consumer preferences for contemporary wedding attire and exploring innovative wedding dress design service models driven by artificial intelligence.

3.2 Research on Intelligent Integration and Assistance at Various Stages of the Fashion Design Process

AI is not only transforming the "outcome" of design but is also reshaping the entire fashion design process. Paola Bertola, Professor at the School of Design at Politecnico di Milano, described the current AI-driven "Fashion 4.0" industrial ecosystem, which is centered around smart factories, smart products, and smart networks. She proposed six innovative principles and design shifts: interoperability, virtualization, decentralization, modularity, service orientation, and real-time functionality.

The participation of artificial intelligence in the design process is fundamentally changing traditional design methodologies. At various stages—including the initial concept, creative ideation, design definition, and design implementation—fashion designers can now independently leverage AI to support their work. For example, Guo Ziyue and Zhu Zongyang, in their article A Review of AI-Assisted Fashion Design Research, divided AI-assisted fashion design into three major phases from the perspective of generative AI's technological logic: fashion detection, fashion synthesis, and fashion recommendation.

In the fashion detection phase, AI enables the classification of historical design styles, patterns, and silhouettes from fashion brands, along with the analysis of fashion feature trends and their popularity cycles. This allows designers to efficiently retrieve existing design elements, ensuring both the continuation and creative evolution of brand DNA. Additionally, AI's intelligent recognition of digital fabrics, including fabric properties and virtual rendering of garment constructions, can significantly reduce errors typically introduced by manual review.

In the fashion synthesis phase, advancements in Generative Adversarial Networks (GANs) and Diffusion Models have profoundly influenced the field of image style transfer. In this phase, AI applications support tasks such as fashion image style migration, automated generation of fashion design sketches, synthesis of fabrics and patterns, and localized modifications or replacements of garment design details. The real-time rendering of design sketches into lifelike garment images helps minimize the proportion discrepancies between design sketches and final products. Moreover, GAN-based style transfer methods inspire fashion designers to develop unexpected and novel design solutions.

The fashion recommendation phase refers to the use of AI algorithms to automatically recommend personalized clothing combinations or design suggestions based on a user's individual preferences, purchase history, body data, and occasion-specific requirements, thereby enhancing the user's shopping experience. Dr. Edit Csanák's 2020 paper AI for Fashion explained that AI can extract data from points-of-sale (POS), geographic information systems (GIS), social media, 3D virtual environments, sensor inputs, and the physical properties of textiles. These data are then translated into intelligible garment reference structures, contributing to the modeling of user design preferences.

3.3 Exploration of Human-AI Co-Creation Models for Sustainable Design

Amid the surge of intelligent technologies, the integration of generative artificial intelligence with innovative eco-friendly technologies has become the new norm in the fashion industry. Increasingly, scholars are turning their attention to the exploration of sustainable design models centered on human-AI collaborative co-creation. This paradigm of human-machine co-creation is redefining the scope of

work, the logic of workflows, and the tools available to sustainable fashion innovators, offering meaningful potential for proactive and future-oriented design practices.

For example, Junghee Jeong and Misook Lee, in their article A Case Study of Human-AI Co-creation (HAIC) in Fashion Design, systematically examined how artificial intelligence and human designers can collaborate through interactive processes to achieve creative fashion design. They proposed four distinct design models: AI-led, human-led, interactive co-creation, and value-integrated co-creation. This fresh research perspective encourages a shift in fashion design from traditional linear workflows to multi-directional interactive mechanisms. It emphasizes co-creation rather than the substitution of human designers by AI, ensuring that human design intuition, empathy, and complex aesthetic judgment are preserved and amplified within AI-assisted processes. Ultimately, this approach fosters the development of a new creative paradigm centered on the complementary advantages of humans and machines.

4. Research Methodology

To thoroughly investigate the potential applications of generative artificial intelligence in sustainable fashion design models from the perspective of design studies, this research adopts a combination of quantitative bibliometric analysis and case study methodology. Starting from the technological foundations of generative AI and deep learning, the study systematically examines the collaborative and assistive functions of generative AI across various stages of the contemporary fashion design process. Furthermore, the research incorporates practical case studies of mainstream AI-based fashion design software to explore the real-world impact and effectiveness of these tools in promoting sustainable development within the fashion industry. The aim of this study is to objectively assess the sustainable applications of generative AI in the fashion sector and to explore and optimize future application pathways and practical models for its integration into sustainable fashion design.

5. Research Analysis

Through the practical use and in-depth analysis of current AI-assisted fashion design software and related case studies, this study investigates the application principles and functional scenarios of existing AIGC (Artificial Intelligence Generated Content) technologies. The research focuses on clarifying the practical logic of AIGC applications within the fashion design process and exploring their potential to drive a sustainable paradigm shift in the industry. On one hand, the study systematically examines the functional integration pathways of generative AI across various creative stages of the fashion design process, while also analyzing the application of typical AI-powered platforms. On the other hand, drawing upon the "Five-Dimensional Integration" (H-T-O-S-M) theoretical model, this research explores, from the five dimensions of Human, Task, Object, Space, and Mirror (Feedback), the evolving role of fashion designers and the formation of co-creation mechanisms within human-AI collaborative design models. By emphasizing data-driven design thinking and interconnected task-feedback loops, this study ultimately aims to establish a fashion design process and design logic optimized for sustainability, providing new

pathways and frameworks for the sustainable transformation of the fashion industry.

5.1 Functional Integration and Application Scenarios of AIGC Technology in the Fashion Design Process

Table 1. Application Types and Platform Case Comparisons of Mainstream AIGC Technologies Across Different Stages of the Fashion Design Process

Machine Deep Learning Technology			**Convolutional Neural Network (CNN)**	**Generative Adversarial Network (GANs)**	**Stable Diffusion Model**	**Existing AI-Assisted Fashion Design Software and Projects**
Core Components			Convolutional layers, pooling layers, fully connected layers	Generator and discriminator	Diffusion, denoising, training	
Main Working Principles			1. Multi-layer convolution and pooling operations progressively extract image features. 2. Fully connected layers perform classification, regression, and other related tasks.	1. Through adversarial training, the generator produces highly realistic data samples. 2. The discriminator learns to distinguish between real and generated samples. 3. Repeated adversarial iterations lead the generator to create increasingly realistic outputs.	1. The stable diffusion model generates realistic image samples through a series of progressive perturbations, gradually enhancing image quality by repeatedly introducing and then removing noise.	
		Classification of	√		√	Fashwell

Specific Applications in the Fashion Design Field	Fashion Detection	**brand styles and patterns**				Vue.ai (by Mad Street Den) Alibaba's iFashion & AI Design Lab
		Fabric texture recognition and analysis	√		√	TextileGAN (MIT) Shima Seiki's APEX4
		Design inspiration generation	√	√	√	AiDLab Greedilous × Tilda (LG AI Lab)
		Market and trend analysis	√	√	√	AiDLab
	Fashion Synthesis	**Local style and color transformation**	√	√	√	Reimagine Retail (Tommy Hilfiger × FIT × IBM)
		Virtual conversion from sketches to finished products	√	√	√	DeepFashion2 (by CUHK) Designovel (KOR)
		Automated fashion design sketch generation	√	√	√	AiDLab
		Fabric pattern design and application		√	√	Greedilous × Tilda (LG AI Lab)
		Fusion of multiple fashion product styles		√		AiDLab (HK)
	Fashion Recommendation	**Fashion campaign production and background replacement**	√	√		LookAI(CHN) Designovel (KOR)

		Fashion styling and personalized recommendation	√	√		LookAI(CHN) Designovel (KOR)
Technical Advantages			Classification, recognition, feature extraction	Generation, creation	Flexibility, open-source, high precision	

Through the practical application and analysis of current AI-assisted fashion design software and related case studies, it has been found that Convolutional Neural Networks (CNNs) are primarily geared towards image recognition, classification, and feature extraction. CNNs are widely employed in fabric recognition, style classification, and the generation of design inspiration. Generative Adversarial Networks (GANs), by contrast, exhibit strong creative potential in the generation of fabric and style samples as well as in cross-modal simulations, and they have been successfully applied to fashion image style transfer and detailed design modifications. The Stable Diffusion model, driven by text-to-image generation, demonstrates superior flexibility and visual precision.

Although these technologies have undergone multiple iterations and upgrades, effectively covering nearly all creative stages within the domain of fashion innovation and design, their points of integration and practical effectiveness in real-world applications are still somewhat limited and remain less than fully satisfactory.

5.2 Applications and Paradigm Shift of Generative Artificial Intelligence in Sustainable Fashion Creative Design

In the field of fashion creative design, persistent challenges such as lengthy product design cycles, severe homogenization, and limited creative output have long been central concerns within the industry. Building upon the previous review of AIGC applications in traditional fashion design, this study, grounded in the "Five-Dimensional Integration" (H-T-O-S-M) theoretical model, systematically analyzes the application characteristics and paradigm shifts introduced by generative artificial intelligence in sustainable fashion creative design. The analysis is structured around five key dimensions: Human, Task, Object, Space, and Mirror (Feedback), providing theoretical support for the evolving logic and future trends of integrating artificial intelligence with sustainable fashion design.

5.2.1 Human: Sustainable Intelligent Collaboration and Role Transformation in Carbon-Silicon Symbiosis

The advent of AI-driven fashion design has fundamentally transformed the role and definition of the human designer. In the process of granting AI its "digital life," the traditional role of the designer has been redefined. The interaction between carbon-based and silicon-based life forms has significantly reduced the need for repetitive, non-essential tasks within the design process. Designers are no longer

solitary creators; they have become managers and collaborators working alongside intelligent tools. The increasing participation of ordinary users—their preferences, interests, attributes, and social networks—has fostered new approaches and methodologies in fashion innovation and design.

Traditionally, designers have held a monopolistic position in the creative hierarchy of fashion innovation. However, with the integration of AI-assisted design, the distribution of decision-making power has shifted. In recent years, whether AI might eventually replace human designers has become a widely discussed topic in academic circles. While artificial intelligence demonstrates formidable capabilities in data processing and image generation, allowing ordinary users to acquire a degree of design creativity and accelerating the democratization of design, it is important to note that the emotional sensitivity, intuitive aesthetic judgment, social responsibility, and cultural and ethical understanding that human designers bring to material selection and design remain irreplaceable.

A compelling example is the world's first AI Fashion Week (AIFW), hosted by Maison Meta in New York in 2023, which attracted significant participation from amateur fashion enthusiasts. This event significantly lowered the technical barriers for public engagement with AI-assisted fashion design and has made the future popularization of collaborative fashion design models involving the broader public increasingly feasible. However, given the current state of technological development, the designer's ability to conduct comprehensive, multidimensional assessments—balancing ecological sustainability, ethical responsibility, cultural significance, and aesthetic values—remains an essential human contribution that technology cannot yet replace, particularly within the context of sustainable fashion design.

Notably, as early as 2008, renowned design scholars Sanders and Stappers introduced the concept of co-creation, proposing it as a new design practice that encourages active participation from users, designers, companies, and other stakeholders from the early stages of the design process. With the emergence of generative artificial intelligence, collaborative creation through AIGC tools has increasingly become a leading trend in contemporary design.

Figure 3. The World's First AI Fashion Week (AIFW), Hosted by Maison Meta in 2023

5.2.2 Task: Bidirectional Data-Driven Processes and Cognitive Liberation

Human experience is often influenced by subjectivity and personal bias, and fashion designers are no exception. Personal preferences and varying levels of professional experience can lead designers to favor specific design styles, with such tendencies carrying strong personal imprints and inherent subjectivity.

Douglas W. Hubbard, in his book How to Measure Anything, argued that in the digital age, everything—whether tangible or intangible—can be measured. The emergence of digital artifacts has shifted the traditionally one-way expression of value and aesthetics in fashion design toward a bidirectional, data-integrated interaction.

From the task perspective, the application of AI in sustainable fashion design revolves around the "data transmission pathways of design tasks." On one hand, AI's ability to analyze and collect data can help fashion designers access large volumes of market insights, consumer preferences, and forecasts of future trends. On the other hand, generative AI can learn from a brand's historical archives, including signature silhouettes, color distributions, and the proportion of different product categories, and can instantly output references that integrate similar brand-specific elements.

A notable example is the 2018 collaboration between the American fashion house Tommy Hilfiger, IBM, and the Fashion Institute of Technology (FIT). In this project, AI-assisted design technology was deeply integrated into the brand's fashion design process, including early-stage trend forecasting and inspiration collection, mid-stage automated sketch generation, and late-stage real-time design feedback. IBM's Watson AI analyzed massive datasets—including social media, fashion blogs, and brand historical sales data—to provide designers with detailed trend analyses and predictive reports.

It is worth noting that, in the early stages of machine learning model training, computers often produced seemingly "imperfect" designs, such as asymmetrical sleeves, oversized hoods, or jumpsuits inspired by vintage dresses. Yet, it was precisely these so-called "beautiful accidents" that offered designers greater freedom of imagination and inspired more unconventional and innovative ideas, ultimately expanding the horizons of creative thinking.

Figure 4. AI-assisted Design System Jointly Developed by Tommy Hilfiger and IBM

5.2.3 Objects: Intelligent Systems for Waste Reduction and Sustainable Design

The fashion industry remains one of the world's leading contributors to resource waste and environmental pollution, particularly across the production, consumption, and disposal stages, leaving behind a considerable ecological footprint. However, the rapid advancement of digital and intelligent technologies is offering the fashion industry new opportunities to minimize material waste throughout the design and

production processes.

Compared with traditional fashion design workflows, modern intelligent design systems allow designers to simulate garment construction and adjust final design styles within virtual environments through the use of virtual sampling and digital twin technologies. This significantly reduces fabric waste typically generated during the production of physical prototypes. Generative AI-assisted design tools can also predict future consumer demand based on brand historical data and market trends, helping to avoid excessive production of fashion styles.

In 2022, LG Corporation in South Korea leveraged its large-scale generative AI model, EXAONE, in collaboration with Younhee Park, founder of the fashion brand Greedilous, to conduct a human-AI co-creation experiment in fashion pattern design. Centered around the theme "The Flower of Venus," the AI artist Tilda quickly generated a series of visual materials aligned with the semantic and aesthetic requirements provided by the human designer. Compared to the traditionally time-consuming process of hand-drawing, iterative ideation, and extensive visual communication, the involvement of the AI system provided fashion designers with mature design concepts and creative inspirations in a much shorter timeframe. This approach significantly reduced resource waste associated with trial-and-error in physical sketching and sample production.

Figure 5. Human-AI Co-creation Fashion Pattern Design Experiment Conducted by LG Corporation and the Fashion Brand Greedilous

5.2.4 Space: Expanding and Extending the Design Space through Virtual-Physical Integration

The fashion design industry has long suffered from the issue of data silos. In the creative design process of fashion products, data flow is still predominantly reliant on manual analysis and experiential processing. Artificial intelligence has broken the physical constraints of traditional garment design, opening up virtual spaces where machines are interconnected, objects are linked to other objects, objects are connected to people, and people are connected to one another. Through communication networks and digital infrastructures, these connections form a dynamic "virtual field."

Compared to traditional fashion design spaces, the interconnectivity of data has significantly expanded the dimensions of innovation within the fashion design field. Renowned British cognitive scientist and AI researcher Margaret A. Boden, in her seminal work The Creative Mind, proposed that AI-assisted innovation is not limited to recombining existing rules and styles but holds the potential to fundamentally reconstruct and transform the design space itself. She defined this as “Transformational Creativity.”

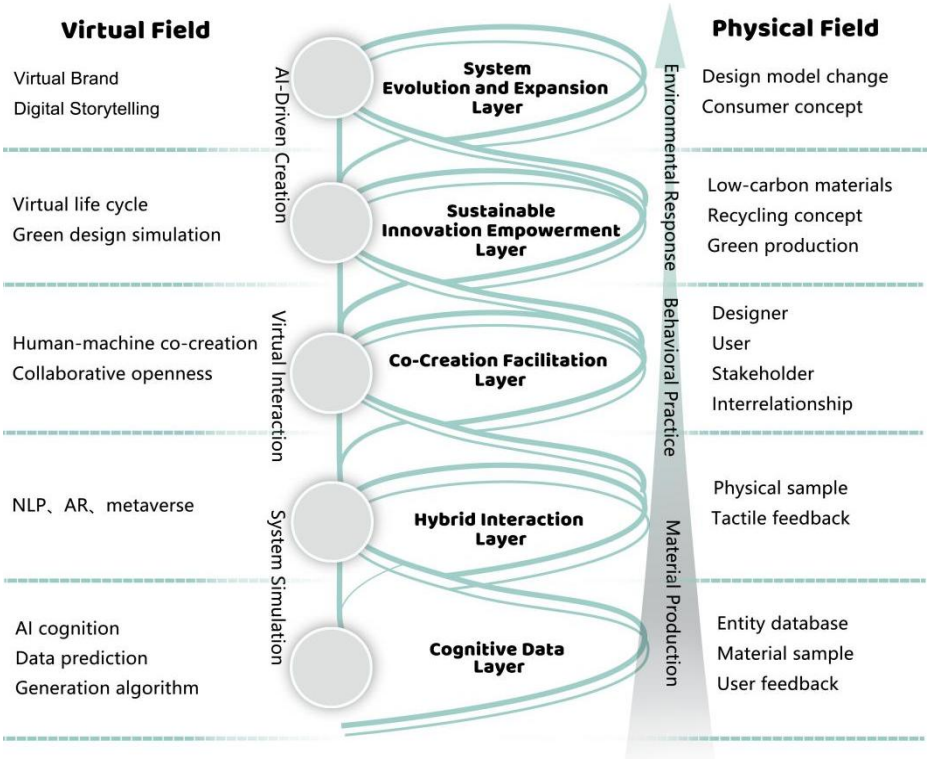


Figure 6. System Model of Virtual-physical Integrated Design Driven by Generative AI

5.2.5 Mirror: Integrated, Shared Design Contexts and Multi-Directional Information Feedback

In the current landscape where intelligent tools are deeply integrated into fashion design, few scholars or industry practitioners have approached the application and development of generative AI in sustainable fashion design from a reflective, mirror-like perspective. This paper proposes that generative AI-related software and systems, in many respects, function as real-time mirrors that continuously reflect and feed back design information.

In the era of big data, generative AI and its supporting data platforms—through multi-directional information flow and interactive feedback—create tightly interconnected relationships among designers, users, and design tools, effectively bridging the entire process from front-end creativity to back-end evaluation.

More importantly, generative AI is not only a mirror that reflects the current design state and evaluates design outcomes but also a predictive mirror that provides foresight into future design directions. For instance, AI-generated eco-friendly fabrics can enable the creation of garments that minimize environmental harm while simultaneously estimating their lifecycle carbon footprint and environmental adaptability.

The widespread application of digital twin technology in garment structure design is a prime example of this "future scenario simulation." The fast-fashion e-commerce company SHEIN, based in Guangzhou, China, uses digital garment modeling to conduct virtual production assessments and facilitate remote order communication, providing a practical foundation for predictive design within this integrated design space.

6. Future Trends

Amid the ongoing wave of intelligentization, the integration of generative artificial intelligence technology with sustainable and eco-friendly principles has become the new norm in the fashion industry. An increasing number of fashion brands are embracing AI and welcoming the technological revolution that is driving a new era of development for the fashion sector.

Looking to the future, the application of generative AI in sustainable fashion design is expected to evolve from passive assistance to proactive collaboration, and from localized support to comprehensive human-AI co-creation. The author argues that the key to the future of deeply integrated, AI-driven sustainable fashion design will lie in adhering to three core principles: human-centeredness, collaboration, and virtual-physical integration. It will also be essential to establish a four-dimensional co-creation ecosystem framework, comprising: Collaborative Innovation、Process Optimization、Virtual-Integrated Space、Human Experience.Only through this systemic transformation can the fashion industry move beyond viewing AI as a mere intelligent tool and embrace it as an ecological co-creator, thereby enabling the realization of a truly sustainable system encompassing design, production, and consumption.

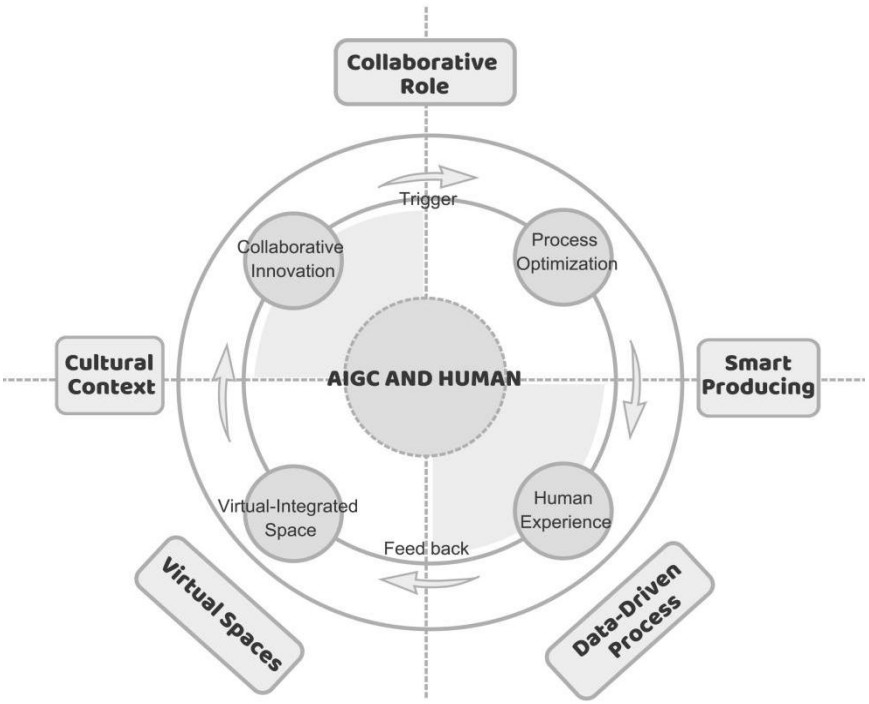


Figure 6. Four-Dimensional Co-Creation Ecosystem Framework for Sustainable Fashion Design Empowered by AIGC

7. Conclusion

Overall, artificial intelligence has brought revolutionary changes to the field of fashion design, offering a new pathway for advancing sustainable development, enriching methods of design innovation, and significantly improving problem-solving efficiency. Its emergence has redefined the scope of work,

operational logic, and tools available to sustainable fashion innovators.

This study adopts the "Five-Dimensional Integration" (H-T-O-S-M) theoretical model as its core research framework, encompassing five key dimensions: Human (subject), Task, Objects (material), Space, and Mirror (feedback). From these five distinct perspectives, this paper systematically examines the application mechanisms and potential value of generative artificial intelligence in sustainable fashion design.

Based on detailed analysis within this theoretical framework, several key conclusions can be drawn. In the human dimension, AI's role in sustainable fashion design is rapidly evolving from a passive auxiliary tool to an active cognitive collaborator. The symbiotic interaction between carbon-based and silicon-based life forms is anticipated to become the mainstream paradigm of future design innovation. In the material dimension, AI enables seamless and highly efficient integration between virtual sketches and physical garment materials, supporting fully automated synthesis and real-time adjustment throughout the design-to-production process.

At the same time, AI-driven collaborative platforms have successfully transcended the traditional boundaries of the design field, facilitating cross-regional, cross-disciplinary co-creation. Supported by real-time feedback mechanisms and data-driven processes, design workflows are steadily progressing toward dynamic iteration and self-optimization.

Through continuous interaction with digital technologies, the alignment between sustainability objectives and digital capabilities is being continuously refined, leading to the reintegration of design innovation elements and further accelerating the systemic transformation of the fashion industry. However, it is also critical to remain alert to the potential negative impacts of these technologies. For fashion designers, it is essential to maintain a constant awareness of technological developments, uphold robust ethical standards, and explore innovative solutions to ensure that the integration of artificial intelligence and design continues to genuinely serve the advancement of human society.

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