Virtual Fashion: Production and Display

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Abstract: *This paper explores two key aspects of virtual fashion: production and display. On the production side, the innovative applications of smart clothing, fabric digitisation and design software are driving the fashion industry towards digital transformation and providing new opportunities for personalised production. Virtual fashion diaplay services, on the other hand, utilise technologies such as AR, VR, XR, virtual reality fitting, Autostereoscopy and other technologies to redefine the consumer's fashion experience, significantly enhancing interactivity and immersion. Looking ahead, with the further maturity and popularity of virtual production and display technologies, it will bring richer and more diverse consumer experiences, but it will also intensify market competition, prompting the fashion industry to continue to innovate in order to meet the growing needs and expectations of consumers.*

Keywords: *Virtual Fashion, Production, Display, Metaverse*

1. Introduction

Virtual fashion, also known as digital fashion, refers to the design, production, display, and sale of fashion products through digital technologies. With the advancement of technology and the arrival of the digital age, virtual fashion, as the forefront of the fusion between fashion and technology, has garnered increasing attention from the fashion industry. This article will summarize the key technologies and applications within the virtual fashion industry from two aspects: production services and display services.

2. Production services

2.1 Smart Clothing

Smart clothing is a type of clothing that can monitor and respond to changes in the human body or environment, with functions such as smart positioning, smart monitoring, smart interaction, and smart regulation. This kind of clothing often integrates high-tech technologies like electronic information technology, biochemical technology, bionic technology, human-computer interaction technology, etc., bringing many conveniences to human production and life and developing towards multifunctional, wearable, diversified, and intelligent directions.

(Image credit: https://touchtech.io/Paris-Fashion-Week-Chalayan-x-Intel)

Figuer 1: One of Chalayan's Spring/Summer 2017 collection outfits

In Chalayan's 2017 Spring/Summer collection "Room Tone," the Intel Curie module was applied,

embedding this module into the glasses and belts worn by models to monitor the wearer's brain activity, breathing, and heart rate, as is shown in figure 1. The design logic of these smart garments is as follows: first, various sensing elements are installed in the glasses to collect information such as the wearer's breathing, heartbeat, brain activity, etc.; subsequently, this information is converted into dynamic images that visualize the wearer's emotions. Intel Curie is a set of highly integrated mini modules released by Intel in 2015, containing motion sensors and low-power Bluetooth communication functions, capable of providing various wearable solutions. Since its release, many clothing brands have embedded Intel Curie into their garments. For example, in 2015, the clothing brand Chromat embedded it into smart sports bras and dresses, using memory alloy in the clothing to adjust the shape of the clothes to fit better and to collect data such as the wearer's body temperature, pulse, and heartbeat. In their Spring/Summer 2017 collection, the clothing brand TOME embedded Intel Curie modules into handbags and bracelets, enabling their garments to not only display air pressure and temperature but also alert the wearer to the presence of harmful substances in the environment.

The Intel Curie module in the cited examples is just the tip of the iceberg when it comes to smart clothing technology and hardware. Recent international smart clothing industry conferences have also showcased technologies such as 3D printing, 3D smart fitting systems, smart fitting mirrors, RFID technology, biometric technology, touch technology, sensor technology, electronic information technology, information management technology, electronic components, smart hardware, IC chips, customization systems,CAM/CAD systems, hanging systems, etc. In addition to the intelligentization of clothing technology and hardware, clothing production equipment is also becoming more intelligent. This is mainly reflected in the intelligent and automated clothing production lines, smart garment equipment, smart textile equipment, smart printing equipment, various intelligent and automated cutting and sewing equipment, robots, laser equipment, ultrasonic equipment, and other intelligent production equipment and technologies. Furthermore, smart materials are also a crucial technology for the intelligentization of clothing. The emergence of high-tech smart clothing materials such as smart fabrics, smart textiles, smart fibers, smart yarns, phase-change fibers, memory fibers, optical fibers, temperature-regulating fibers, smart gel fibers, graphene, nanomaterials, quantum technology, and photochromic materials etc., have accelerated the progress of clothing intelligentization.

The research and development of the aforementioned technologies and materials have driven the development and application of smart clothing in fields such as medical health, national defense, sports and fitness, fashion and leisure, home life, aerospace, and education. For example, smart clothing embedded with various sensors can monitor physiological signals such as respiration, heart rate, blood pressure, blood oxygen, and body temperature, serving the medical industry by aiding in the prevention, monitoring, and treatment of diseases.Color-changing clothing and infrared camouflage, which can change color according to the surrounding environment and detect the presence of biochemical weapons, are commonly used in the military field. The demand for smart clothing in the sports sector is also increasing as it can provide athletes with physiological data and offer support and protection. For instance, Athos has launched smart clothing equipped with a chip and multiple sensors that transmit the monitored data to smartphones via Bluetooth, making it popular among professional athletes. Some fashion designers utilize the interactive functions of smart clothing to create changing patterns on a single garment, with emotional interaction, body interaction, cognitive interaction, and aesthetic interaction being the most commonly used methods. Dr. Kitty Y.M. Yeung, a scientist and fashion designer, has conducted extensive experiments on "human-garment interaction." Additionally, virtual reality (VR) and augmented reality (AR) technologies have also propelled the development of smart clothing. For example, the Teslasuit developed by Tesla Studios in the UK is the world's first full-body VR touch experience suit, allowing wearers to feel sensations such as being hugged, hit by a bullet, or scorched by the sun in a desert. CaptoGlove, designed for VR, AR, and mixed reality (MR), is a wearable smart glove using Flexpoint flexible bend sensors. It is breathable, washable, and compatible with smartphones, tablets, TVs, and computers, replacing traditional tools like game controllers, remotes, and keyboards, providing users with a more immersive experience.

2.2 Fabric Digitization

If smart fabrics have opened the door to the fashion metaverse through interactive functions, then fabric digitization technology builds a ladder leading the fashion industry to virtual fashion. As virtual runways and virtual models become new trends in fashion displays, the frequency of digital clothing will increase. The creation of digital clothing mainly relies on CAD modeling, simulation rendering, and dynamic simulation and other technologies. Following the production sequence of fabric and pattern digitization, 3D simulation and rendering, and video output, fabric digitization is the first problem to be

addressed in digital clothing production. "Fabric digitization" refers to the process of collecting information on physical fabrics and converting it into digital formats.Scientists and fabric companies have made numerous attempts to digitize fabrics based on their optical and physical properties. The optical properties of fabrics include visual appearance characteristics such as color, texture, luster, size, thickness, pattern, transparency, and structure, which can currently be collected through photography or scanning technology and then processed into digital information via software. The physical properties of fabrics, such as drape, elasticity, bending, compression, and dynamic features under wind, can be digitally simulated and fine-tuned using computer enumeration methods. Real-world fabrics often possess complicated nonlinear, anisotropic bending stiffness properties.Over the past few decades, fabric engineers and scientists have developed a variety of standard test methods relevant to bending stiffness, including the cantilever method, the heart-loop method, the drape method and the hanging method [1].However, in practice, because of the wide variety of textures and materials, some fabrics are also wrinkled, fuzzy, blemished and burred, making the digitisation process much more difficult. In order to solve these difficulties, scientists have also conducted many explorations based on deep learning.For example, the Style3D team from Lingdi Technology, led by graphics expert Dr. Wang Huamin, proposed an AI prediction model for simulating parameters, greatly enhancing data collection speed.

Dynamic simulation technology for flexible fabrics requires integration with body modeling, skeletal animation, and other technologies to achieve complete virtual clothing design. Some companies already provide comprehensive digital solutions for the clothing industry, such as TG3DStudio, HOHENSTEIN, and Heartdub, offering 360° body scanning, fabric scanning, 3D clothing design software, online retail experience software, and online collaboration services, enhancing the fashion industry's efficiency.

The Total Appearance Capture (TAC) system created by X-Rite, an American company,is a complete system comprising precision instruments and intuitive software applications.TAC can highly automate the virtual material and rendering processes.For example, the TAC7 scanner for 3D material scanning and fabric scanning can capture and store the color, texture, gloss, and other surface appearance characteristics of physical material samples.The virtual materials generated from the scans can be directly used in different lighting environments without further adjustments. Additionally, the virtual materials include a metadata system that facilitates the management andsharing of materials.

If "fabric digitisation" is the process of digitising physical fabrics, then "digital fabrics" is the process of converting the digital into the physical, using data and tools within a computer system to create new fabrics that can be used in the virtual world as well as transformed into real fabrics. MIT has created the world's first "digital fibre" in 2021, and this fibre can store and process data and information.

2.3 Design Software

Compared to traditional clothing design processes and tools, 3D technology for clothing is becoming a valuable assistant for companies and designers due to its efficiency and convenience. Using such computer-aided design tools can significantly save human, material, time, and space resources. Major 3D clothing software on the market includes CLO 3D, Marvelous Designer, TUKA 3D, Browzwear, C-Design Fashion, Romans CAD, Fusion 360, and Style 3D and so on.

2.3.1 Style 3D

Style 3D, developed by Zhejiang Lingdi Digital Technology Co., Ltd., is a 3D digitization platform serving the global apparel industry.Its 3D digital design software features core advantages such as 3D modeling, physical simulation, and rendering,providing users with a complete digital solution from online collaboration, rapid prototyping, design review recommendations, direct connection to production, and online exhibition and sales. The 3D digital development process for apparel significantly shortens the research and development cycle and enhances efficiency.Table 1 provides a clear comparison of the steps involved in both the traditional sample-making method and the 3D online development process, highlighting the streamlined and efficient nature of the latter. Digital design has the potential for speed. It is possible to alter colors, patterns, and forms with a single button click. Conversely, traditional design necessitates a more laborious, manual procedure [2]. Compared to traditional design, which has lower upfront costs but higher material expenses, digital design, despite its initial hardware and software investment, leads to long-term savings and offers more flexibility for editing and sharing. However, in traditional fashion design, you can directly touch and feel the fabric, but this experience cannot be replicated in digital design.

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Table 1: Comparison of steps between traditional sample-making method and 3D online development process

Aspect	Traditional Sample-Making Method (15-30 days)	3D Online Development Process (3-7 days)
1. Planning	✓	✓
2. Design Drafting	✓	✓
3. Material Preparation	✓	-
4. 2D Pattern Making	✓	✓
5. Sample Making	✓	3D Sample Making
6. Photography & Videography	✓	-
7. Manual Costing	✓	-
8. Sample Revision	✓	-
9. Final Approval	✓	-
10. Production Order	✓	Smart Production Material Generation
Additional Features	-	Online Collaboration

2.4.2 CLO 3D

This intuitive and user-friendly 3D design software supports online pattern making, virtual fitting, and rendering, applicable to all stages of clothing design and development. It offers video tutorials to guide users, available on social media platforms like Bilibili and YouTube. The software allows users to redesign and convert 2D garment patterns into 3D, create clothing styles, adjust fabric visualizations, and test the comfort of virtual garments.The software's physical parameter models, including cutting, stretching, and bending stiffness, make it easier for users to design various garments.

2.4.3 Marvelous Designer

Developed by the same Korean company as CLO 3D, Marvelous Designer shares core technology with CLO 3D but is mainly used in the CG, animation, and gaming industries, while CLO 3D focuses on the clothing industry. The key difference is that CLO can import/export DXF-AAMA or DXF-ASTM files, which can be sent to the manufacturer during production. Marvelous Designer can create virtual clothing compatible with other 3D software and allows real-time clothing modification and fitting. Virtual garments created with this software can be made to reflect the details of various fabrics as well as the pleats and draping of the garment.

2.4.4 TUKA 3D

TUKA 3D, a simple and easy-to-use 3D clothing design software developed by Tukatech in the USA, supports multiple languages. Its virtual model data comes from scanning real models' bodies. It also provides a dynamic fitting simulation environment, can simulate moving, dancing, running and other

states of the fitting animation. It digitizes fabrics through testing real fabric samples. When integrated with the TUKAdesign system, clothing pattern making and scaling can also be realized.

2.4.5 Browzwear

Like many apparel 3D R&D companies, Browzwear provides 3D apparel design, development, marketing and collaboration solutions for the apparel industry, and currently develops software and platforms such as Vstitcher, Lotta, Stylezone, Fabric Analyzer, SmartDesign, and others.Vstitcher converts 2D patterns into 3D prototypes for clothing design and development. Lotta can be used for rapid 3D design and style creation, providing users with fabrics, accessories, graphic prints, lines, colour swatches and other functions. Stylezone is a collaborative platform for web and mobile, involving all stakeholders in the design-to-sales process. Fabric Analyzer is Browzwear's open platform ecosystem that accurately reads fabric performance data for 3D software. SmartDesign has smart templates that include information on silhouettes, accessories, colours and processes from the factories of various apparel brands. Browzwear also launched Browzwear University, an online platform for learning clothing digitization.

2.4.6 C-Design Fashion

Developed by C-DESIGN in France, C-Design Fashion is an online clothing design tool used throughout the clothing design process, including product lifecycle management (PLM) and online sales. It offers solutions for sustainable development and environmental protection, serving as a platform for creating, editing, organizing, and sharing.

2.4.7 Romans CAD

Romans CAD is a CAD software specifically developed for leather and footwear products. It supports sample making, editing, and modification operations. This digital service platform with CAD and PDM (Product Data Management) is a cloud tool that facilitates effective communication between designers and manufacturers.

2.4.8 Fusion 360

Table 2: System and language support

Name	System	Language
CLO 3D	Mac,Windows	English, Simplified Chinese, Traditional Chinese, Japanese, Korean, Spanish, French, Italian, Portuguese, etc.
Marvelous Designer	macOS 10.13 High Sierra or later ; Windows 7 or later (64-bit)	Korean, Arabic, Simplified Chinese, Traditional Chinese, English, Japanese, French, Russian, Turkish, Portuguese, Italiano, Spanish, etc.
TUKA 3D	Windows 7 or later (64-bit)	English, Chinese (Simplified and Traditional), Japanese, Korean, Spanish, French, Italian, Portuguese, Russian, Turkish, Arabic, etc.
Browzwear	macOS 10.15 (Catalina) or laterWindows 10 or later (64-bit)	English, Chinese (Simplified and Traditional), Spanish, French, Italian, Korean, Japanese, Portuguese, Russian, Greek, Hungarian, and Thai, etc.
C-Design Fashion	Windows 8 or later (64-bit); Mac: the software requires a compatible Windows environment via virtualization tools.	English, French, Spanish, etc.
Romans CAD	Windows 10 or later (64-bit); Mac users can run Romans CAD using virtualization tools such as Parallels Desktop or Bootcamp to create a Windows environment on their Mac.	English, French, Spanish, etc.
Fusion 360	Windows 10 or later (64-bit); macOS 10.15 (Catalina) or later	German, English, Spanish, French, Italian, Japanese, Korean, Chinese (PRC), etc.
Style 3D	macOS 10.15 (Catalina) or later; Windows 10 or later (64bit,NVIDIA)	English, Chinese (Simplified and Traditional), Korean, Japanese, etc.

Developed by Autodesk, Fusion 360 is a 3D modeling software used in digital processing, industrial design, mechanical design, and clothing design and simulation. It can create clothing, footwear, and accessories. This software is also the first cloud-based collaborative platform for CAD, CAE, CAM, and

Project Management, facilitating instant communication between designers and companies.

Finally, Table 2 summarizes the computer systems required to use the aforementioned software and the languages supported by these software programs, helping readers to prepare accordingly before use.

2.5 Digital Sample Library for Clothing

Traditional clothing production processes include style design, pattern design, fabric and accessory selection, process design (cutting, sewing, ironing, etc.), and finally, transmission in paper form within and outside the clothing enterprise. The development of the internet and digitization technology has improved production efficiency in the clothing industry. The establishment of digital resources libraries for clothing enhances the competitiveness of clothing enterprises. For example, one of the projects of the Ningbo Digital Library in China, the "Textile and Apparel Specialty Library," includes the "Textile and Apparel Journal Database," "Textile and Apparel Enterprise Information Database," "Apparel Style Image Library," "Apparel Pattern Image Library," and the "Ningbo Clothing Museum Collection Database." Among these, the "Apparel Pattern Image Library" is a pattern database that includes menswear, womenswear, and children's wear.

Establishing a "digital sample library for clothing" saves time and prevents losses due to manual pattern-making errors. Therefore, many companies have established or are establishing their own "digital sample libraries." Various companies and scientists have designed and attempted to build such libraries. Jiangsu Sunshine Group has established an MTM sample database. The MTM (Made to Measure) system focuses on individual customers, with highly automated features. The core data resources for MTM systems include human body size databases, clothing style databases, pattern libraries, pattern modification rule libraries, fabric libraries, clothing size specification libraries, and size archiving rule libraries. Leatech's MTM.assyst software system helps companies establish standard pattern and grading databases, manage product data classification, and retrieve relevant cut pieces from the sample database for personalized automatic pattern modification upon receiving an order. The software interface can even connect with production, order, and ERP systems, as well as 3D body scanners and virtual fitting software like Vidya. Many other technology companies can also help enterprises build "digital sample libraries," such as the ET system from Buyi Technology, which provides rich parameterized template libraries for classic styles. Users can choose and modify style templates as needed or create their own parameterized template libraries. The system also includes "clothing component libraries" and "clothing template frame libraries" to provide users with digital clothing components and paper pattern templates.

2.6 XR Garment Making

With advancements in digital technology, the field of clothing design is gradually or already being infiltrated by technologies like virtual reality (VR), augmented reality (AR), and mixed reality (MR), making virtual clothing design possible. Virtual clothing design moves the design process from 2D to 3D, integrating multiple sensory experiences like auditory, visual, and tactile, making the design process more interactive.

The once highly popular VR painting tool Tilt Brush enables clothing design in a three-dimensional space but is still limited to the artistic design aspect. Hologarment, developed by Shanghai Qinger Intelligent Technology Co., Ltd., is a clothing design software based on Microsoft Hololens, as illustrated in figure 2. It is a multifunctional clothing design platform integrating virtual reality, remote collaboration, real-time communication, and image physical simulation. Hologarment creates a virtual working environment that allows for remote collaboration, enabling clothing designers, models, factory workers, and salespeople to communicate and collaborate simultaneously in a virtual environment despite being in different locations. During communication, detailed issues in the clothing design process, such as patterns, fabrics, wearing effects, and fine adjustments, can be presented, improving communication efficiency and reducing communication costs. Hologarment's intelligent drawing assistance system allows designers to create three-dimensional drawings in the virtual space, with the system automatically generating industrial flat patterns that can be sent to remote factories for sample garment production. Additionally, it is worth mentioning the "NAO" virtual weaving system, also developed by Qinger Technology, which utilizes artificial intelligence algorithms to usher in a new era of unlimited fabric structure design.

(Image credit: https://t.cj.sina.com.cn/articles/view/6065571359/16989461f00100lbix?from=tech)

Figure 2: Hologarment Clothing

3. Display Services

The development of digital technology offers viewers richer and multidimensional ways of experiencing. Fashion brands are also utilizing metaverse display methods to offer more diverse and engaging experiences, placing greater emphasis on interactive and immersive experiences. These approaches fully engage multiple senses of the audience, including auditory, visual, tactile, olfactory, and gustatory experiences, thereby better achieving emotional and spiritual resonance with the audience. This helps establish closer connections with consumers and fulfills marketing communication objectives. These display methods include, but are not limited to, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR) and Extended Reality (XR), as well as Autostereoscopy, 3D mapping, and 360° holographic projection and so on.

3.1 Metaverse Fashion Week

In March 2022, the gaming platform Decentraland hosted the world's first "Metaverse Fashion Week" (MVFW), free to anyone with a Decentraland account. Both traditional luxury brands (Dolce&Gabbana, Elie Saab, Tommy Hilfiger, etc.) and digital native brands (The Fabricant, Auroboros, Republique, etc.) participated, marking a groundbreaking moment for the fashion industry. This virtual fashion week featured runway shows, virtual retail stores, after-show parties, live music, seminars, and more. The virtual mall surrounding the show was modeled after Paris's Avenue Montaigne, with some brands even purchasing virtual real estate for displaying or selling products. Each brand's show had unique features; for example, Dolce&Gabbana used cat avatars as models, Phillipp Plein planned a DJ performance, and Unxd had models flying out of blooming lotuses. The production process of this virtual fashion show involved 3D technology, virtual engines, motion capture, and scanning of real models. Other notable virtual fashion show examples include the 2020 Helsinki 3D Virtual Fashion Week and Gary James McQueen's virtual fashion show "Guiding Light." Balenciaga had already moved its Fall 2021 fashion show into the VR game "Afterworld: The Age of Tomorrow." In 2022, Dior released its first metaverse fashion show in China, in collaboration with China's first virtual world platform "XiRang," guiding viewers to register and watch the AR virtual stage show in "Meta Ziwu."
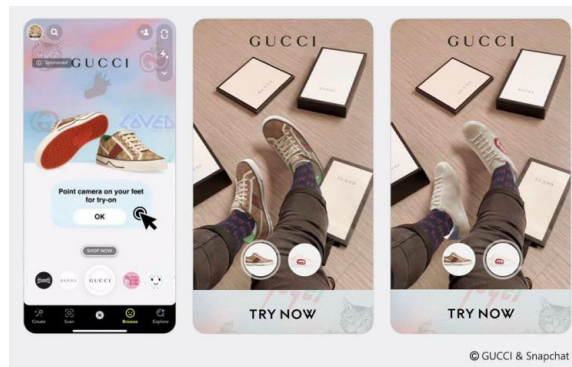
3.2 3D Mapping and Autostereoscopy

(Image credit: https://maioranomagazine.com/gucci-cosmogonie-a-castel-del-monte-tutto-quello-che-abbiamo-visto/)

Figure 3: Gucci Cosmogonie Early Spring 2023 Show

Gucci Cosmogonie Early Spring 2023 collection show used mapping technology, as depicted in Figure 3, in collaboration with Bureau Betak to project starry sky images onto a castle, creating a stunning and culturally rich blend of reality and virtuality. Autostereoscopy outdoor advertising is also becoming popular among luxury brands, often placed in bustling commercial districts, attracting countless pedestrians to stop by it. Louis Vuitton collaborated again with Japanese artist Yayoi Kusama at the end of 2022 to launch an autostereoscopy advertisement in Tokyo, Japan. Shanghai's landmark building "MetroCity Ball" in Xujiahui was upgraded to the world's first autostereoscopy spherical screen, capable of displaying various information, including fashion luxury brand advertisements.

3.3 AR, VR, XR

Virtual Try-On gives consumers more confidence when making purchases by letting them see how clothes will fit and appear on their bodies. This improves the overall shopping experience and reduces the possibility of returns, which increases client loyalty and pleasure.[3] In 2020, Gucci launched virtual fitting using "Snapchat AR"'s augmented reality technology, allowing users to virtually try on four pairs of Gucci shoes by pointing their smartphone camera at their feet, as demonstrated in Figure 4. If they liked the shoes, they could purchase them directly by clicking the "buy now" button in "Snapchat AR". Previously, Snap Inc. had also collaborated with Gucci to release limited edition smart glasses. Gucci had already added AR fitting features to its iOS app in 2019, including virtual jewelry fitting. Other fashion brands, such as Estée Lauder, Adidas, Nike, Burberry, LV, Hugo Boss, and others, have also used AR technology for virtual makeup and clothing fitting activities.

(Image credit: https://www.perfectcorp.com/business/blog/commerce/top-luxury-retail-trends-twenty-twenty-three)

Figure 4: Gucci shoes via Snapchat's AR

In 2013, Nicolas Rossi and Julian Ball founded the VR shopping site "Avenue Imperial" in London, UK. This virtual shopping site has since attracted mid to high-end brands such as Jimmy Choo. Tommy Hilfiger have also launched VR experiences in its physical retail stores, allowing shoppers to witness the debut of the designer's latest collection with Gear R devices. Fashion brands Rebecca Minkoff and Balenciaga offered similar VR shopping experiences. Beauty brand Charlotte Tilbury released a VR perfume ad starring supermodel Kate Moss. Louis Vuitton launched a VR experience called "Asnières Immersive," allowing global audiences to explore Louis Vuitton's craftsmanship from a first-person perspective. The "Prada VR Project" enabled audiences worldwide to learn about the brand's story through VR glasses. Users could experience Prada's Tokyo, New York, and Los Angeles Epicenter flagship stores and the Prada Foundation in Milan and Venice, watch fashion shows, and understand the behind-the-scenes craftsmanship and services through VR headsets or glasses on platforms like YouTube VR, VEER, Oculus, Youku, and Facebook.

The newly launched Apple Vision Pro creates an immersive virtual shopping environment through XR technology. Many fashion brands and shopping platforms are gradually adapting to the market changes brought about by technology, making adjustments accordingly. For instance, the shopping platform Mytheresa has partnered with visionOS developer "Obsess" to create a series of innovative digital experiences, offering an unparalleled luxury customer journey. This allows customers to emotionally immerse themselves in various collections and occasions. J.Crew's fashion brand shopping app "J.Crew Virtual Closet" and Lowe's home renovation and design service app "Lowe's Style Studio" as depicted in Figure 5, both use Apple Vision Pro to provide consumers with virtual immersive shopping experiences.

(Image credit: https://www.lowesinnovationlabs.com/projects/lowe-s-style-studio)

Figure 5: Lowe's Style Studio

3.4 Online and Offline Stores

As mentioned earlier, Apple Vision Pro supports virtual environment shopping, allowing users to interact with virtual sales assistants, ask questions, and receive instant feedback. They can also communicate with experts through real-time video chat to learn more about product design inspirations. On June 28, 2024, Apple Vision Pro was officially released in China, with Taobao Vision Pro upgraded to version 2.0, enabling users to browse and purchase billions of products on this spatial computing device.Alongside this, Tmall Luxury Pavilion updated its customized luxury 3D experience space. Brands like Maison Margiela have leveraged Taobao Vision Pro to provide consumers with a new 3D immersive shopping experience on the Taobao platform, significantly enhancing the accuracy of shopping decisions. In product displays, fashion luxury brands are increasingly using a combination of virtual and real elements. Some physical stores enhance their interaction with consumers by employing digital media technology and art. For example, Hermès' "The Magic Shoe" is a product display solution that integrates digital media interaction with Hermès' shoe products. When viewers touch the shoes, a multimedia device under the shoes generates corresponding animations, accompanied by pleasant music, allowing the audience to have a multidimensional experience while interacting with the product. Adidas installed a multimedia display screen in its Nuremberg store, where viewers can interact with the products on the screen through body movements and purchase their desired items.

Canada Goose's concept store "The Journey" employs a combined "online and offline" retail and display approach, allowing consumers to browse and purchase all products through online devices while visiting the store under the guidance of staff. Notably, this concept store incorporates numerous technological elements to create an interactive and immersive experience space. These features include virtual "ice crack" effects on the floor, immersive videos of snowy landscapes, and a hyper-realistic cold room simulation.

Virtual try-on technology also provides consumers with a unique shopping experience. In 2022, global retail giant Walmart launched the AR virtual try-on feature "Be Your Own Model" through its acquired virtual fitting room platform, Zeekit. IOS users can upload photos in the corresponding app to experience the try-on effect. Within seconds, virtual clothing is overlaid on the consumer's image, rendering realistic effects such as natural shadows and the drape of the fabric.

In 2024, British department store Selfridges announced a collaboration with social platform Snapchat to create an unprecedented AR dressing room pop-up event at its Oxford Street flagship store. This event combines technology and fashion, centering around annual sports events such as the UEFA European Football Championship, the Paris Olympics and the Wimbledon Open. Consumers standing in front of the mirror are instantly transported into a place that blends the virtual and real worlds, where they can experience virtual try-on services.

3.5 Virtual Fashion Exhibitions

Major fashion luxury brands place great emphasis on spreading brand culture and enhancing brand image. Collaborating with artists and art institutions presents an excellent opportunity to elevate their brand image. Many fashion brands hold exhibitions aimed at reviewing their history, promoting their culture, and showcasing their classic products. ecause fashion luxury goods have their own connection with artworks in terms of their craftsmanship, design and association with artists, they are often exhibited in art galleries, museums and other art institutions and moulded to look like art exhibitions. As digital
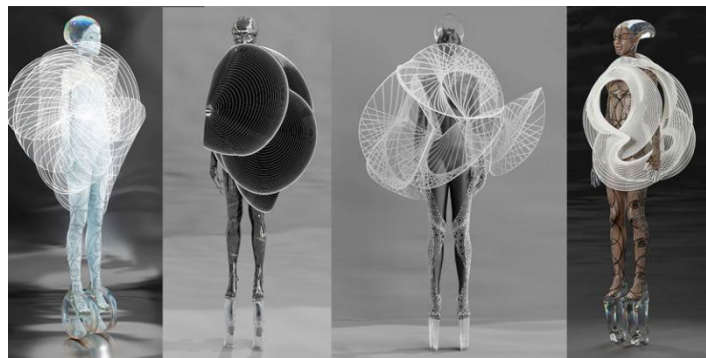
technology permeates the exhibition industry and becomes a popular display method, these "art exhibitions" by fashion luxury brands have also incorporated numerous elements of the metaverse.

The "Hermès' Wanderlan" exhibition uses a scattered storyline to recreate eleven scenes of Parisian life, incorporating digital technologies like holographic projection and 3D mapping to create a magical exhibition hall. Bvlgari's "VivaTech" exhibition in Paris created a virtual metaverse exhibition hall, simulating Roman streets and buildings, featuring virtual appearances of its CEO and brand's jewelry, and offering digital shopping conveniences for viewers.

3.6 NFT

Some digital-native brands, such as The Fabricant, Auroboros, and Republique, as well as independent digital artists creating virtual fashion designs, have been mentioned previously in this article. Some of them have even established their virtual fashion houses. Interested readers can follow virtual fashion designers like Davina India, Anna Kreamon, Mishi McDuff, Larissa Castellano Pucci, Anna Lisa Liedtke, Diana Perfilieva, and Marc-O-Matic.

Moreover, several traditional haute couture fashion luxury brands have begun collaborating with artists to create their own NFT products. For instance, Givenchy partnered with renowned graffiti artist Chito to release 15 NFT works. Similar collaborations include Gucci with artist Floria Sigismondi, Jimmy Choo with artist Eric Haze, Louis Vuitton with artist Beeple, Salvatore Ferragamo with artist Shxpir, and Balmain with artist Jeff Cole. The digital-native fashion brand RTFKT co-created a series of virtual sneakers with artist Fewocious. In 2022, Threeasfour collaborated with artist Shingo Everard to launch AR virtual fashion and partnered with Dressx to present animated NFTs, as illustrated in figure 6.

(Image credit: https://www.nokillmag.com/articles/ronald-van-der-kemp-threeasfour-iris-van-herpen-fall-2022/)

Figure 6: Threeasfour Fall 2022

3.7 Co-branding with video game platforms

In 2019, Louis Vuitton has co-branded with the video game "League of Legends," where the character Qiyana, the assassin in the game, could have expensive Louis Vuitton virtual outfits. Louis Vuitton also custom-made trophy cases for "League of Legends." Similarly, Moschino co-branded with the video game "The Sims 4", releasing a series of virtual clothing, bags, and jewelry, with some items made into real versions. Hermès launched its mobile game "Hermès H-pitchhh," featuring the brand's "horseshoe" element as the game's main character. Burberry launched games "BBounce" and "B Surf" in 2019. In 2021, Burberry collaborated with the creative game development platform Mythical Games to release a series of NFT virtual products in the game "Blankos Block Party," which included a unicorn character named Minny B as a Burberry Blanko. In 2022, Burberry launched five virtual Lola bags on the global online gaming platform Roblox, created by designer Builder Boy, and introduced a co-created game and capsule collection with "Minecraft". Fendi collaborated with Chinese artist Wang Lingchen to create an immersive digital game, "Fendi Playground", aimed at fostering engagement and connection between the digital community and Fendi. Balenciaga also created virtual fashion for characters in the video game "Fortnite." A 2023 study by the video game platform Roblox found that over half of Gen Z users are willing to spend up to $10 per month on their digital avatars' outfits. In 2023 alone, Roblox users purchased 1.65 billion digital fashion items.

3.8 Digital Humans

As digital human technology develops, virtual idols have become popular in the fashion industry. In 2018, Lil Miquela, Shudu, and Noonoouri were the first virtual influencers to attract attention from the fashion industry. Shudu Gram, created by the digital company "The Diigitals," and Noonoouri, a virtual influencer and fashion blogger, have collaborated with numerous fashion brands. Lil Miquela, an American digital human, is active on social media as a fashion influencer, singer, actress, and model, with a large following and numerous brand partnerships. Lil Miquela has collaborated with brands like Prada, Balenciaga, Moncler, Burberry, Chanel, and more, with some photos featured in fashion magazines like Vouge, Elle, L'Official. Prada even invited her to manage the brand's account during the 2018 Fall/Winter show. Her daily outfits, similar to many fashion bloggers, have boosted sales for many brands' products. She has also played the role of a designer, collaborating with Dior Homme jewelry designer and AMBUSH founder Yoon Ahn to launch a co-branded sweatshirt that sparked a buying frenzy. In 2020, Burberry introduced a digital double of supermodel Kendall Jenner in its summer collection; a year later, the brand launched a digital double of supermodel Naomi Campbell.

3.9 Artificial Intelligence and Robots

Generative artificial intelligence has the capability to enhance, speed up, and automate various aspects of the fashion industry, from coding and design support to sales team empowerment. 73 percent of fashion executives stated that generative AI will be a key focus for their businesses in 2024, yet only 28 percent have experimented with it in their design and product development processes.[4]

ANNAKIKI's 2024 AW Milan fashion show, themed "The Era of Artificial Intelligence," featured eight AI-assisted outfits. Armenian artist Joann's AI-generated artwork has gained popularity among fashion brands, leading to collaborations with Gucci, Valentino, Versace, Marc Jacobs, and others. Figure 7 shows one of Joann's digital campaigns for "Versace Grecca Goddess Bag".

(Image Credit: https://www.joann.ai/works/versace-grecca-goddess)

Figure 7: Digital Campaign for Versace Grecca Goddess Bag by Joann

Balenciaga used AI robots instead of traditional models to showcase its limited-edition Qixi Festival products during the Chinese Valentine's Day in 2022, with the campaign shot by photographer Andrea Artemisio. In 2023, Levi's announced a partnership with Amsterdam startup Lalaland.ai to use AI models to showcase products on various body types, skin colors, and ages, aiming to sustainably increase the diversity and number of models.

Additionally, fashion brands also utilize AI technologies such as utomatic speech recognition and natural-language processing to extract keywords that facilitate product upgrades. For example, the company determined that it could improve the "color" and "tightness" of one type of jeans based on its analysis of keywords in consumer feedback. It found that these issues were caused by inconsistent production processes across different fabric suppliers, so the supply chain team guided its suppliers on how to resolve these issues.[5]

4. Conclusion

As technology advances and the digital age progresses, virtual fashion, an emerging industry, is gaining popularity. This paper has mainly discussed virtual fashion from two aspects: production and display. The integration and application of these innovative technologies are redefining and driving the

digital transformation of the fashion industry. Virtual fashion not only brings unprecedented possibilities for future fashion innovation and consumer experience but also becomes a key driver for the industry's new development model.

In terms of production, virtual fashion showcases innovative applications in three key technological areas. First, smart clothing uses advanced sensors and electronic information technology to monitor human data and interact with the environment in real-time, providing personalized wearing experiences. This technology has broad application prospects in medical, sports, and smart living and can change the way users interact with clothing. Second, fabric digitization uses CAD modeling and simulation rendering to convert physical fabrics into virtual models, significantly accelerating design development cycles and promoting sustainable and customized production. Third, design software innovations, such as cloud-based clothing design software, enhance designers' creative efficiency and precision, facilitating global production and supply chain management coordination.

Virtual fashion display services, including co-branded with electronic gaming platforms and AR, VR, and XR technologies, redefine fashion experiences. Consumers participate in metaverse fashion weeks through headsets, enjoying immersive virtual reality. AR technology allows virtual fitting at home, reducing the inconvenience of physical fitting. Autostereoscopy and 3D Mapping technology make virtual displays more realistic. Digital humans and AI technology enhance customization and shopping experiences, while NFT technology innovates digital marketing, and online and offline store combinations offer new shopping fun. Virtual fashion display services are revolutionizing traditional fashion, pushing it towards a digital and personalized future.

In the future, virtual production and display technologies will become more mature and widespread. Consumer experiences will become more personalized, with interactivity and immersion becoming mainstream. The content created by virtual fashion will be richer and more diverse, but market competition will also become more intense. Therefore, fashion companies need to master cutting-edge virtual fashion technologies to better adapt to the changing market environment and consumer demand brought about by virtual fashion.

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