

Empowering Fashion Design and Intelligent Manufacturing with Digital Twins in the Metaverse Era

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Abstract

In the era of metaverse, digital twin technology is not only applied to traditional industrial and aerospace fields but also begins to empower fashion design and intelligent manufacturing, ushering in a new business model and a new era of value creation. This article discusses the application of digital twin technology in the fashion industry and the digital value it brings. In the fashion industry, digital twin technology is mainly applied in five areas: the design and development of fashion products, identity verification, tracking the entire lifecycle of fashion products, intelligent manufacturing of digital twin clothing factories, and immersive experience of fashion display. In addition, digital twin technology realizes the digital value added to clothing by connecting to NFT ecosystems, games, and other emerging fields. On the one hand, the value of physical clothing is enhanced by using physical products plus digital products; on the other hand, digital-twin clothing as independent digital assets opens up new markets and business models, providing new ways for brands to extend their influence into the virtual world. Digital twin technology has revolutionized the traditional mode of the fashion industry, created new business opportunities and value growth points for it, and will further promote the industry's digital transformation and intelligent development in the future.

Keywords: Metaverse, Digital Twin, Digital-twin humans, Digital-twin clothing, Digital-twin Factory

1. Introduction

1.1 Digital Twin

As early as the 1970s, NASA and its Soviet rival, the Russian Federal Space Agency (Roscosmos), pioneered the use of the concept of a twin to represent a spacecraft and its components, reflecting (or mirroring) the state of a spacecraft on a mission. The earliest definition of a digital twin was given by Prof. Michael Grieves of the University of Michigan, USA, who introduced the concept of a "virtual digital representation equivalent to a physical product" in 2003 (Grieves, 2011). To date, the definition of a digital twin widely accepted by the industry was given by Glaesseggen and Stargel in 2012: "a complex product simulation model that integrates multi-physics, multi-iscale, and probabilistic simulation to reflect the state of a real product in real time" (Glaesseggen & Stargel, 2012).

In the metaverse era, digital twin technology has not only been applied to traditional industrial and aerospace fields but has also begun to empower fashion design and intelligent manufacturing (Cheng & Kuzmichev, 2018; Peng & Kuzmichev, 2018; Alam, Kabir, & Mirmohammadsadeghi, 2023). By constructing digital twin models of clothing, designers, and manufacturers can perform highly accurate simulation and optimization in virtual environments, which not only enhances the innovation ability of fashion design but also greatly improves the efficiency of fashion production and quality control (Santos, Gabriel, Amaral, Montevechi, & Queiroz, 2021). With the emergence of digital-twin humans and digital-twin clothing in the metaverse, consumers can experience unprecedented personalization and interactivity in the virtual world, bringing tremendous innovation potential and market opportunities to the fashion industry. The application of this technology enables the fashion industry to achieve the goals of intelligence, personalization, and sustainability, opening up new possibilities for the future of digital fashion and smart manufacturing and ushering in a new business model and a new era of value creation.

1.2 Digital-twin Clothing and Digital-twin Humans

In the fashion industry, digital twin technology is used to create virtual versions of clothing products and humans, giving rise to the concepts of digital-twin clothing and digital-twin humans.

1.2.1 Digital-twin Clothing

Digital-twin Clothing refers to the virtual 3D model generated in virtual space according to the physical fashion products (Durão, Zancul, & Schützer, 2021; Kuzmichev & Yan, 2022). As a virtual mirror image of the physical clothing products, the digital-twin clothing can interact and coexist with the physical clothing to become a dynamic twin capable of self-updating and self-feedback, with the characteristics of dynamic simulation, information traceability, and identity uniqueness (Wagner & Kabalska, 2023). The dynamic simulation of the digital-twin clothing is reflected in the fact that it can maintain real-time synchronization with the physical clothing products at various stages of design, manufacturing, sales, use, disposal, recycling, etc., and can be monitored, edited, and updated. The information traceability of the digital-twin clothing is reflected in its ability to centrally store massive amounts of information about the physical clothing product and its associated contents, creating an exclusive digital clothing archive. Physical clothing can exist in the metaverse as a uniquely identified digital twin version under the validation of NFT technology.

1.2.2 Digital-twin Humans

The digital-twin human is a dynamic virtual 3D model that reproduces the image of a real person in virtual space (Miller & Spatz, 2022), which, as a mirror image of the real body, must reproduce the structure, shape, voice, expression, and movement of the real human body 1:1. At the same time, as a kind of real-time and multithreaded doppelgänger, the digital twin realizes the virtualized configuration of the physical, social, and mental attributes of the real person (Wang et al., 2024). As an agent of the real body, the digital twin can interact with others on behalf of the real body and perform various tasks as the real body in virtual space. The real-time doppelgänger is unique in that it is a 1:1 dynamic twin manipulated by the real body proper (Figure 1), and the multithreaded doppelgänger, as an agent of the real body, is a doppelgänger presence that responds in real time away from the real body proper (Figure 2).

Currently, the technical application of the digital-twin humans is booming in the fashion industry as a three-dimensional visualized virtual model for high-precision static reproduction of human body structure, shape, and movement. For example, Balenciaga collaborated with 3D scanning studio Rigsters to realistically capture 50 fashion models and their movements using body photogrammetry 3D scanning technology. These models were applied as digital twin humans in the online 3D clothing showcase and video game scenes for the Fall/Winter 2021 collection (Figure 3). In addition, the presence of a twin facilitates direct access to a 3D human model of the real body during the design process, allowing designers to optimize clothing on the mirrored digital body, demonstrate wearability, and multithreading through user feedback. With the popularization of technology, digital-twin humans in the fashion industry will be capable of using interactive symbiosis and real-time dynamic mapping. They will be able to exist in different clothing experience scenarios in the form of multithreaded doppelgängers to satisfy the clothing requirements of different experience scenarios.



Figure 1. Doug Roble, the head of the software development department at Digital Domain, presents his real-time 1:1 digital double, Digi Doug, during a TED talk

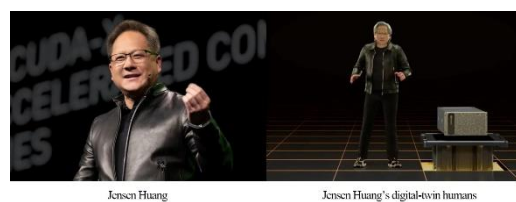


Figure 2. NVIDIA showcased the multithreaded digital double of their CEO Jensen Huang at the 2021 GTC conference



Figure 3. The Balenciaga Fall/Winter 2021 collection presented fashion models and their movements as the digital-twin humans through digital scanning

2. Application of Digital Twin Technology in the Fashion Industry in the Metaverse Era

In this article, we will explore the application of digital twin technology in the fashion industry in the era of metaverse from five aspects: design and development of fashion products, identity verification, tracking the whole life cycle, intelligent manufacturing of digital twin clothing factories, and immersive experience of fashion display.

2.1 Design and Development of Fashion Products

Advanced design visualization: By creating a digital twin of a physical clothing product using computer-aided design (CAD) software and 3D modeling technology, designers can visualize their creative ideas in a virtual environment, quickly visualize the clothing product they envision, and more intuitively understand how the clothing will fit and drape on the human body before producing physical samples and testing their feasibility.

Speed up the design iteration process: Digital twins enable a rapid process of design iteration and solution experimentation, allowing designers to quickly make changes, test different materials, colors, and patterns, and fine-tune their designs without requiring extensive physical sample experimentation. In the development process, clothing products need to be constantly evaluated and corrected through sample trial production. This repetitive iteration takes a lot of time, and the use of CLO 3D, Style3d, and other professional 3D clothing design software to create the digital twin of the clothing through the real-time link between the 2D layout and the 3D clothing model to speed up the process of trial production of the sample clothing. The designers can carry out online designers can design and modify, directly by adjusting the 2D pattern drawing or 3D virtual samples to achieve the desired design effect, replacing the traditional production and development process of cutting fabrics to sew the physical samples, to repeat the process of trial plate for design adjustments. The traditional model takes about two weeks, while the 3D virtual sample takes only about 8 hours, which shortens the iteration time from design development to sample production in traditional clothing production and saves the material cost of repeated sampling.

Efficient design collaboration: The digital twin of physical clothing can be used for subsequent adjustments and modifications to the design, facilitating clear communication and seamless collaboration between designers, manufacturers, and other stakeholders and shortening the product development cycle. Companies such as Style 3D's Style3D Cloud platform, Clo3D's CloSet platform, and Guangdong Shidi Intelligent Technology Company's Revofim platform. The generated 3D virtual samples can be directly uploaded to the 3D design collaboration platform to meet the needs of designers, customers, buyers, suppliers, and other parties for rapid communication, sharing, and collaboration. One of the participants can directly review and annotate the 3D virtual clothing online through the cloud, use the platform-tools to point out the parts of the clothing that need to be changed, and then leave a message and confirm the publication of the other collaborators will receive the relevant changes. After confirming the publication, other collaborators will receive the relevant modification instructions.

Shorten product development cycles: By minimizing the design iteration process and facilitating collaboration within the fashion supply chain, digital twins provide fashion brands with a competitive advantage by significantly reducing the time it takes to bring new collections to market.

Enhanced product personalization: Digital twin technology also enables the personalization of clothing products, allowing designers to create personalized, customized clothing based on an individual's body type to achieve a precise fit and size design, providing consumers with a tailored shopping experience. Currently, it is possible to directly obtain customized 3D clothing models and 2D samples based on an individual's body shape by using digital twins of clothing that can be worn on a digital twin of the human body through virtual clothing migration technology (Qingwen, Zhaohui, Rong, Huanhuan, & Sibang, 2023).

Make product quality predictions: Designers and manufacturers can use digital twins to test different clothing

materials, production methods, and even pricing strategies to improve product quality, reduce production time, and lower maintenance costs. For example, clothing brand Levi's uses digital twin technology to simulate the look and feel of jeans after multiple washings to ensure that they maintain their quality over time. In addition, leading sports brand Adidas creates virtual replicas of its footwear and clothing to simulate how they will perform in different conditions and environments, allowing Adidas to make changes to its designs before manufacturing, improving the quality and durability of its products.

2.2 Identity Verification of Fashion Products

With the convergence of blockchain and NFT technologies, digital-twin clothing can be used as "digital IDs" to authenticate physical clothing. The digital ID of digital-twin clothing is a unique identifier associated with the virtual representation of physical clothing. It typically contains rich information about the clothing, covering aspects such as its design, materials, production, sustainability, and ownership. This data is critical for authentication, customer engagement, transparency, and supporting circular economy and sustainability initiatives in the fashion industry. By leveraging digital twin technology, brands can provide consumers with an immutable record of a product's origin and history, as well as detailed information about the product's materials and manufacturing process, helping clothing brands achieve a more efficient and personalized authentication process and creating a new model for customer experience and engagement. For example, in June 2021, Swiss watchmaker Louis Erard collaborated with designer Alain Silberstein to create three luxury watches, each with a twin digital body in the form of an NFT (Figure 4), which is enabled by blockchain technology to identify the authenticity of the watch and show the technical specifications associated with the product. Purchasers can access the corresponding "digital double" of their watch to verify the product's authenticity. Private information can be added to each NFT digital twin watch according to personalization requirements, and buyers can provide a unique code for their watch.

To connect the physical to the digital, physical identifiers such as QR codes, NFC chips, or RFID tags must be added to the physical clothing product. Eon is currently using these physical identifiers to create digital twins of its physical clothing products for clothing brands such as Pangaia, H&M, Gabriela Hearst, and others (Figure 5). Each identifier corresponds to a unique digital ID. When the QR code on the physical clothing is scanned with a smartphone, it opens a Web page with all the information about the product, allowing consumers not only to verify the product's authenticity but also to get information about the product details and styling tips and advice.



Figure 4. Physical watch and digital- twin watch



Figure 5. Physical clothing and digital-twin clothing by Pangaia

2.3 Tracking the Entire Lifecycle of Fashion Products

The digital twin of clothing products can continuously record usage status data, usage environment data, and other content of Physical clothing products so that the digital twin of finished clothing products can be monitored in real time during the usage process. In addition, based on real-time data and historical data records of Physical clothing products, the digital twin of clothing products can, on the one hand, accurately predict the remaining service life of the products and provide predictive maintenance suggestions; on the other hand, it can expand new recycling business models for clothing brands, such as leasing, resale, digital closet, peer-to-peer exchange, styling services, reuse and recycling, and so on. For example, French fashion brand Chlo é is experimenting with digital IDs on the labels of its Spring/Summer 2023 clothing collection for traceability, restoration, and instant resale online. Owners of the clothing can scan an NFC tag or QR code on the label to receive an ownership number, then take a picture of the item and upload it for easy and quick resale through the brand's secondhand microsite, powered by Vstiaire Collective. Consumers can also access details of their clothing's eco-certificate, as well as care and repair instructions.

2.4 Intelligent Manufacturing of Digital Twin clothing Factory

Digital twin technology recreates clothing manufacturing scenarios in virtual space to create a digital twin model of a physical clothing factory that replicates specific components, assets, production lines, and entire systems of

the clothing manufacturing process. Depending on the scope and complexity of the manufacturing operation, four key components are created: component twin, asset twin, system twin, and process twin, which together create a comprehensive digital twin factory environment for clothing manufacturing. The digital twin factory contains not only the physical characteristics of the simulated object but also information about its behavior, function, lifecycle, etc. By dynamically sensing the production object and the manufacturing process and then realizing the two-way mapping of the physical factory and the digital twin factory, the manufacturer is able to monitor and analyze the objects and systems in the physical production process in real-time based on the digital twin factory, so as to realize the optimization of the production scenario, which plays the following key roles:

Realize the intelligent management of production elements: The digital twin clothing factory realizes the visualization, verifiability, and intelligent management of production elements through real-time dynamic synchronization of data from factories in the real world. It maps physical things such as workers, materials, equipment, tools, and environment, as well as production processes and real-time shop floor data. Using efficient data integration capabilities, it collects and processes operational data from multiple sensors, IoT, and other devices, such as clothing modeling parameters, production information, product design specifications, and quality information. This data is synchronized in real-time to ensure that the digital twin factory is consistent with the physical factory, providing manufacturers with accurate and timely data references.

Achieve efficiency and reduce consumption in the manufacturing process: The digital twin clothing factory monitors production processes, equipment performance, and environmental impact in real-time by managing and optimizing all aspects of the manufacturing process, including production flow, material movement, and machine status. By continuously monitoring key metrics and simulating different manufacturing scenarios, manufacturers can make quick decisions, identify inefficiencies, make timely corrections, optimize resource allocation, streamline operations, and reduce material and energy consumption. The digital twin factory enables R&D simulations of production processes, reducing trial and error costs and increasing productivity. By integrating digital twin data, different manufacturing strategies and plans are simulated and evaluated, eliminating errors and filtering out cost-effective production solutions.

Enhanced supply chain visualization: The digital twin factory improves supply chain visualization by monitoring raw material sourcing, manufacturing operations, inventory levels, product flow, delays, and obstacles in real-time. It integrates data sources such as supplier information, logistics data, and production schedules to provide real-time visibility and traceability, helping clothing companies track production progress and identify potential bottlenecks, delays, and inefficiencies. This visibility enables manufacturers to make proactive decisions, take immediate corrective action, ensure on-time delivery and operational efficiency, and optimize supply chain processes.

Enabling predictive analytics for the manufacturing process: The digital twin clothing factory uses real-time data and sophisticated analytics to predict production outcomes, assess resource needs, and optimize scheduling to ensure on-time delivery and reduce costs. Manufacturers can use digital models to simulate different production scenarios in real time, perform what-if analyses, optimize workflows, and improve efficiency. By integrating data from sensors, the Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML), the digital twin factory generates predictive analytics to support data-driven decision-making. This combination of technologies helps predict future events and trends, proactively manage production processes, reduce downtime, and improve overall efficiency.

Enable remote maintenance of machines and equipment: By implementing sensors and IoT technologies, the digital twin can monitor production parameters in real time and collect real-time data on machine and equipment usage, such as temperature, humidity, and machine performance. This allows manufacturers to anticipate maintenance needs and detect potential failures before they occur, enabling early troubleshooting and proactive maintenance and repair of production equipment (Alkhamash, Karaa, Bhouri, Abdessalem, & Hassanien, 2022).

2.5 Immersive Experience of Fashion Displays

Digital-twin clothing helps create a more immersive and compelling experience for people. Digital-twin clothing can be applied to the display of virtual fashion products, the display of virtual shows, the display of space and items in virtual shopping stores, and the mixed display of physical and virtual items and virtual space through VR, AR, and other technologies. The virtual display of clothing is more interactive and simulation, and it is convenient for consumers to understand the design details and three-dimensional wearing effect of clothing, which can lead to purchasing behavior (Lei & Tianyu, 2021).

Using VR, AR, and other technologies, digital clothing is twinned with virtual try-on and display. For example,

the fashion e-commerce platform Farfetch is working with the virtual fashion store DressX to promote its new physical clothes by pre-positioning digital clothing for online celebrities. For Italian fashion brand Marni's Spring/Summer 2022 collection, physical clothing was presented as digital-twin clothing in an interactive lookbook (Figure 6). Marni digitized physical clothing to bring selected runway looks from its Spring/Summer 2022 collection into the virtual world through an immersive digital experience, "WEAR WE ARE," created through a 3D lookbook, an AR interface, and an immersive virtual environment where users can navigate and purchase 3D products to showcase Marni's physical clothing offerings. The virtual world created on Marni's website can be accessed directly from a computer or mobile phone, allowing users to enter a dreamlike, uninhabited island where twin digital versions of the physical models and clothing are placed, where they can freely explore the island and view the clothing on these digital bodies, select them from a product window that pops up on the right, and save their favorite clothing to a wish list. In addition, users could interact with the looks from the runway show, which Marni transformed into a 3D lookbook, allowing them to interactively explore the 3D looks in 360°, add selected clothing to the list, and purchase them directly.

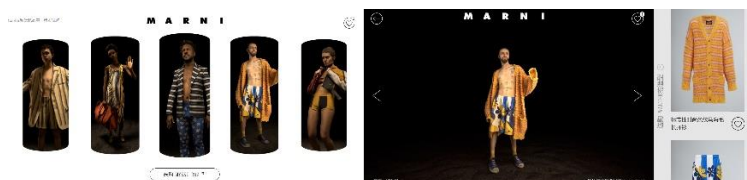


Figure 6. Interactive 3D lookbook

3. Digital Twin Empowerment Digital Value-Added for Clothing in the Metaverse Era

The fashion industry's layout in the metaverse, integrating with the NFT ecosystem, gaming, and other emerging fields, has introduced new operating rules, redefined the boundaries of traditional fashion products, and accelerated the expansion of the boundaries between physical and digital products in the current phase. The transformation process from physical clothing to digital-twin clothing is a value-added process that realizes the digital value-added of physical clothing. On the one hand, clothing brands utilize the way of adding physical products to digital products to make more profits than selling physical products alone and enhance the value of physical products; on the other hand, digital-twin clothing is transformed into a digital asset that can be sold individually in the virtual world, creating entirely new digital value, which can give a new digital life and new income opportunities to physical clothing design.

3.1 Digital-twin Clothing Enhances the Added Value of Physical Products

Fashion brands are beginning to extend their creative designs into the metaverse realm by operating in a real-with-virtual manner. Users can get the digital-twin clothing products presented in the form of NFT (Non-Fungible Token) when purchasing physical clothing. The digital-twin clothing is not only a digital asset belonging to the user but also helps the brand to realize the membership system and user community building in the metaverse. It becomes an important gateway to establish a new association between the brand and the user, and the brand establishes an exclusive community in the metaverse for the NFT holders, and provides them with brand-exclusive experiences and service activities. The user's relationship changes from participation to ownership, and the digital-twin clothing in the form of the NFT digital collection becomes a passport to connect online and offline. For example, in June 2022, clothing brand Prada is launching a limited-edition shirt design in its "Timecapsule" collection, where consumers who purchase a physical shirt will receive free digital-twin clothing in the form of a reciprocal NFT (Figure 7), which can be linked to the physical product under Ethereum-based blockchain technology. The physical product and each digital NFT will have a unique number associated with each physical shirt. In addition, Prada is offering exclusive benefits to NFT owners, who will be able to join the brand's online community, "Prada Crypted," to unlock a wider range of benefits and experiences, as well as be invited to a series of private offline events. They will also have the opportunity to be invited to a series of private offline events, such as "Prada Mode" in Dubai and "Prada Extends" at Art Basel Miami Beach.



Figure 7. Physical Shirts from Prada's "Timecapsule" Collection and their Corresponding Digital-twin Clothing

Physical clothing also comes with non-NFT digital-twin clothing. Some fashion startups offering digital services have pioneered new methods of combining physical clothing with digital-twin clothing. When purchasing physical clothing, customers receive digital twin versions that can be used in virtual games and social platforms like Decentraland, Minecraft, and Roblox. These digital-twin clothes can also be personalized, adding extra value to the physical assets of fashion companies. For example, London-based fashion brand Martina Spetlova has partnered with Seamm so that when a customer purchases a physical Martina-designed clothing from the offline store Selfridges, the hang tag is accompanied by a QR code provided by Seamm. The customer can use their phone's camera to scan the QR code on the clothing label to download and install the Seamm app, which then activates the corresponding twin digital version of the clothing. The corresponding digital-twin clothing is activated (Figure 8). The twin is added to the shopper's virtual closet in the Seamm app, complete with authenticity identifiers and AR try-on functionality. At the same time, the twin can be transferred and used in the virtual world of Decentraland to dress the user's avatar (Figure 9). In addition, customers can change the color, pattern, and other design details of the digital twin through the customization function in the application (Figure 10) and try on the clothing virtually through the AR try-on function, which, on the one hand, enriches the customer's personalized customization experience and increases the level of engagement. On the other hand, this customer experience is also used to experiment with product design and test the more popular and suitable color schemes and pattern prints of the clothing through the customer's design. On the other hand, this customer experience is also used to experiment with product design and test more popular and suitable color schemes and pattern prints through the customer's design in order to influence the brand's decision-making on the design of future collections.



Figure 8. Customers purchase physical clothing with seamm QR codes, scan QR codes using the seamm app to activate corresponding digital-twin clothing



Figure 9. obtain digital-twin clothing versions wearable in decentraland

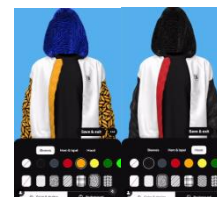


Figure 10. Customization Feature in the Seamm App

3.2 Digital-twin Clothing Opens Up New Digital Value

Digital-twin clothing can be sold as a digital asset, giving new digital life to the physical clothing design and generating new digital value. Clothing brands continue classic physical designs into digital-twin clothing, realizing the inheritance of brand elements and cultural genes, expanding new markets with digital products, and continuing the brand's influence in the virtual world. For example, in a large-scale online exhibition on the virtual world platform Roblox, the clothing brand Gucci replicated an identical digital-twin bag based on the Wine God bag released in 2015, which had a market price far higher than the price of the physical bag (Figure 11). The London department store Selfridges collaborated with the clothing brand Paco Rabanne to create a digital-twin version of the brand's iconic 1966 concept clothing, giving new life in the virtual world to clothing that cannot easily be worn in reality (Figure 12).

The combination of digital-twin humans and digital-twin clothing can provide users with a highly personalized experience. Digital-twin humans can be generated based on a user's body data, while digital-twin clothing can be tailored to the digital doppelganger, allowing for personalized clothing fitting, matching, and presentation. For

example, the Fashion Innovation Agency (FIA) at the London College of Fashion, University of the Arts London has created digital-twin humans as digital human stylists that can provide personalized fashion advice to people by analyzing detailed user data, such as current location, local services, weather, and community information, and based on pre-scanned digital-twin clothing stored in the user's digital closet (Figure 13).



Figure 11. Gucci Dionysus Bag on Roblox



Figure 12. Recreating paco rabanne's early conceptual physical clothing in the form of digital-twin clothing



Figure 13. Digital human stylists

In the metaverse, besides digital-twin humans, there are also character digitized humans who are avatars of virtual images that play the role of their own imagined persona, different from their real body persona, in virtual space. Digital avatars become extensions of the self, and just like real people in the real world, these digital avatars need to dress and groom themselves. Digital fashion allows people to express themselves, show their individuality, or relate to others by wearing specific clothing or accessories to gain a sense of belonging. As a result, digital fashion, which is presented to consumers through gaming and social media platforms, opened up as life moved online and consumers began to look for new ways to express themselves, and virtual worlds became the new channel for all kinds of products and services, leading to a new type of retailing called Direct-to-Avatar (D2A), D2A is a business model in which brands, companies, or individuals sell virtual clothing without physical items directly to avatar owners, a model that allows brands to bypass the physical supply chain so they do not have to worry about supply chain management issues such as inventory, logistics, and distribution. D2A business models allow audiences to wear branded clothing, accessories, and skins for their avatars through virtual gaming platforms, social media platforms, and digital avatar creation platforms. These digital clothing products are typically created and sold by brands, independent digital designers, or custom content creators.

The cross-border fusion of fashion and gaming has led to a new direction of expansion for digital-twin clothing, which becomes a gamified variant of the physical clothing product and evolves into a gaming asset with some specific aesthetic attributes. Such digital-twin clothing can be transferred to the virtual worlds of video games and metaverses to dress avatars in virtual gaming platforms, virtual social platforms, and digital avatar creation platforms, adding value to the use of fashion companies' virtual assets. For example, American clothing brand Ralph Lauren, an early adopter in the D2A space, extended its physical clothing line into the virtual world in August 2020, partnering with Snapchat to launch a virtual clothing line for user avatars on Bitmoji, creating digital twin versions of brand classic physical items such as double-breasted blazers, racing jackets, striped rugby shirts, and vibrant sports jackets (Figure 14). In 2021, the brand combined its vintage styling with physical pieces from its current summer collection to launch a virtual clothing line on the Korean virtual social platform Zepeto (Figure 15), allowing users to dress their 3D avatars with exclusive products, including 12 complete looks and 50 products. From in-game merchandise to the digitization of physical products, the line between digital and physical fashion is becoming increasingly blurred.



Figure 14. Ralph Lauren Collaborates with Snapchat to Launch Digital Twin Versions of Classic Physical Clothing



Figure 15. Ralph Lauren Collaborates with Zepeto to Launch Digital Twin Versions of Physical Products

4. Discussion

It can be seen that under the wave of digitization in the metaverse era, all contents can be mapped in the metaverse through digital twins. The digital twin of clothing connects the real and the virtual through digital technology, achieving the cross-boundary integration of physical digitization and digital physicalization, and the real-life and virtual worlds will become more intertwined, and the boundaries will be blurred. With the rapid popularization and application of new-generation information and communication technologies, such as big data, artificial intelligence, machine learning, Internet of Things, and cloud computing, digital twin technology in the fashion industry has shown a wide range of application prospects and great potential, bringing about profound changes from design and development, identity verification, lifecycle tracking, intelligent manufacturing, and immersive experiences, and bringing about a digital value-added evolutionary direction for the industry. Combining physical clothing with digital-twin clothing enhances the added value of physical products while opening up a new digital value as a digital asset and expanding the influence of brands in the virtual world. In short, digital twin technology not only revolutionizes the traditional mode of the fashion industry but also creates new business opportunities and value growth points. In the future, with the continuous progress of digital technology and the deepening of its application, digital twins will definitely further promote the digital transformation and intelligent development of the fashion industry, bringing more innovation and change.

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