

Tracing the History of Digital Fashion

Adil Boughlala¹  and Anneke Smelik¹

Clothing and Textiles
Research Journal
1-16

© 2024 ITAA



Article reuse guidelines:

sagepub.com/journals-permissions

DOI: 10.1177/0887302X241283504

journals.sagepub.com/home/ctr



Abstract

This article provides the short and non-linear history of digital fashion, arguing that it is entangled with the development of digital environments and virtual worlds. Unlike material clothes, digital fashion end products are created digitally, for digital use. Digital fashion can range from digital skins for gamified environments or virtual influencers to superimposed images, Augmented Reality filters, Non-Fungible Tokens (NFTs), and digital twins or phygital fashion. We trace the emergence and development of digital fashion through pivotal themes: from its relation to virtual worlds, the Internet, and e-commerce, to the implementation of avatars and fashion in videogames, to the commercially led digital fashion industry that has emerged in the past few years in what is called Web 3.0, and finally, we look at the recent surge of interest in artificial intelligence and its potential complications for digital fashion.

Keywords

digital fashion, phygital, videogames, virtual worlds, metaverse, avatar, NFT, augmented reality, virtual reality, fashion 4.0

In the film *Clueless* (Heckerling, 1995), Cher Horowitz starts her day by choosing an outfit to wear by booting up her now-considered bulky computer that has all her clothes cataloged as images. With the click of a few buttons, Cher browses through her digital inventory, selecting and matching clothes to create a cool and coherent outfit. The computer will then evaluate her choices, telling whether the outfit is a “mis-match” or not. If it is a match, the computer displays a full-body image of Cher in the outfit she has chosen. She can then pick these items from her real-world wardrobe. While such technology did not yet exist in the 1990s when the film was released, this scene is a prime example of how digital fashion was imagined a few decades before it came into being. Digital fashion today is, perhaps predictably, far more complex than the simplistic portrayal seen in *Clueless*.

In this article we trace the not-yet-written history of digital fashion and its emergence and development in the last few decades. In this context, “digital” refers to anything involving computer technology and virtual environments, encompassing products and experiences created, used, and experienced through digital means. Digital fashion is digitally created clothing, accessories, and cosmetics; they are end products that can be consumed and engaged with mainly in digital and virtual space.¹ Digital fashion can be digital skins or dress for gamified environments, digital skins for virtual influencers, superimposed images,

¹Department of Cultural Studies, Radboud University, Nijmegen, the Netherlands

Corresponding Author:

Adil Boughlala, Department of Cultural Studies, Radboud University, Erasmusplein 1, Nijmegen 6525 HT, the Netherlands.
Email: adil.boughlala@ru.nl

Augmented Reality filters, NFTs (Non-Fungible Tokens), and digital twins (also known as *phygital* fashion, digital representations of physical clothes) (Chan et al., 2024). Digital fashion functions in virtual environments, for example on the bodies of avatars, and is not limited by physical boundaries like material clothes.

Given the rapid technological advancements and the growing integration of digital practices in the fashion industry, it is crucial to document and understand the evolution and impact of digital fashion. This research aims to fill the gap in historical documentation and provide insights into the transformative effects of digital technology on fashion. In this article we provide the brief and bumpy history of digital fashion by tracing the emergence and development of digital fashion through pivotal themes: from its relation to virtual worlds and the Internet, to the implementation of avatars and fashion in videogames, to the commercially led digital fashion industry that has emerged in the past few years in what is called Web 3.0, and finally, we look at the future with artificial intelligence. We do so because virtual worlds have pioneered the concept of virtual fashion; fashion elements have long been incorporated into videogames; and Web 3.0 has introduced new opportunities to digital fashion through blockchain technology, which popularized the concept outside of a gaming context. We present the asynchronous history of digital fashion not as a linear development, but rather as a series of thematic convergences that evolve at different speeds in contemporary digital fashion practices. For our study of the extensive digital fashion landscape, we have applied a historic approach using both online and offline primary sources, including a literature review, museum visits, and attending digital fashion events both physically and digitally.²

Fashion and Digital Technology

Old and new technologies play a pivotal role in fashion, from age-old techniques like spinning and weaving to factories on an industrial scale for CMT (cut, make, trim), to the role of smart devices today. We understand technology in the basic sense as “the use and understanding of tools, technique and processes that use these tools” (Tortora, 2015, p. 1).

Already in the 1980s and 1990s, a digital revolution in fashion commerce took place. Fashion brands started exploring possibilities of e-commerce (electronic commerce) and the Internet as a means of selling physical fashion online. While forward-thinking, e-commerce in the fashion industry initially failed due to sectoral issues such as constraints of dial-up speeds, limited stock capabilities, and unsustainable funding from venture capitalists, but also a lack of clear vision in the fashion industry (Crewe, 2013). The Internet at this point was in an early phase, and fashion brands were still exploring its potential for the fashion industry. Yet, the digital revolution of the 1980s marks an important landmark in the history of digital fashion, as it had lasting material and cultural impacts on the fashion sector – such as the development of e-commerce infrastructure, online marketing tools, and direct-to-consumer (DTC) models – that led to the mediatization and digitalization of fashion as we know it now.

The McKinsey Apparel report from 2017 (Berg et al., 2017) indicated that 3D design, virtual prototyping, digital printing, RFID (radio frequency identification), automated manufacturing, and demand planning would highly impact the fashion industry by 2022. Indeed, computational technology has changed the fashion system. In their 2022 report, The Business of Fashion and McKinsey & Company expect that by 2030 fashion companies’ investments in technology will double to keep up with digital natives and create competitive edge (Amed et al., 2022). By now digital media have become intrinsic to the practices and discourses in the fashion industry, which has also led to fashion brands, professionals, and influencers cultivating their digital presence (Rocamora, 2017, 2018, 2022).

The obvious but important role of the Internet in today’s shopping for clothes cannot be overlooked. The COVID-19 pandemic limited buying in physical shops, which led to more consumers

buying clothes via the web (Amed et al., 2022; Casini & Roccetti, 2020). This development follows the ubiquitous adoption of the Internet and social media, which led to practices of fashion becoming shaped by and for digital media (Choufan, 2022; Rocamora, 2017).

While online shopping has become quite familiar, many other technological developments are still in their earlier stages. The fashion industry is developing software to improve online shopping, for example, to get a sense of the materiality of textiles and fabrics online (Jang & Ha, 2023). Software is also being developed to perfect virtual fitting on an individual body to avoid the problems of waste due to the high percentage of clothes that are bought online and returned and discarded unused. Other developments include virtual closet apps such as *DressX* and *Zero10* that allow users to buy digital-only clothing and wear it in real-time through their smartphone camera using Augmented Reality (AR). A final example of recent developments are virtual closet apps like *Whering*, which is inspired by the film *Chueless*, through which one can scan one's physical clothing in the wardrobe and display and style the items on the smartphone. The app visualizes data based on the wardrobe, giving not only recommendations for outfits to wear based on previous wear history but also for the next purchase to minimize overconsumption.

Fashion 4.0

Although technologically mediated, clothes are still made of materials. Digital fashion differs from material clothes because it exists exclusively in the virtual realm—in cyberspace. Digital fashion can therefore be situated in Industry 4.0, the so-called Fourth Industrial Age (Schwab, 2017). Nobile et al. (2021) summarize the history of fashion and technology through the Four Industrial Revolutions, from steam, electricity, and information technology to “the so-called Industry 4.0,” which “contributes to shape the fashion industry through an advancement of digital technologies, such as cyber-physical spaces, Internet of Things, computing tools, personalization, localization, and digitalization of fashion heritage” (p. 293). Bertola and Teunissen (2018) call the adoption of technologies to create, disseminate and consume fashion in a digital environment: “fashion 4.0.” It is characterized by the implementation of new modes of production and consumption that blur the boundaries between the digital and physical. These smart technologies bring forth new forms of fashion, “smart fashion products” that operate in cyber-physical spaces (Bertola & Teunissen, 2018).

The digital transition has shaped and will continue to shape the fashion landscape in new ways. Cyber-physical clothing systems make it possible to realize interaction, for example by embedding sensing technology in the fabric (Wang et al., 2020). The Internet of Things (IoT) integrates fashion into an interconnected web of physical objects that keep track of and generate information, contributing to “big data” (Papahristou et al., 2017). Perhaps most visibly, the integration of blockchain systems – digital systems in which (transactions of) digital ownership of goods and cryptocurrency is stored and traced continuously – into the fashion industry has not only resulted in tracking and influencing consumer behavior patterns (Pal & Yasar, 2020), but has also introduced fashion NFTs (Non-Fungible Tokens) to the fashion market. Because of these blockchain systems, users can own and spend cryptocurrency, for example on fashion NFTs in digital and virtual spaces. These NFTs are ascribed a cryptographic signature that is native to the blockchain and unique to each token. Simply put, each NFT – such as a three-dimensional image of a dress – is unique in code, no matter its similarity to other NFTs.

Artificial intelligence, personal data, and user contribution can create highly personalized fashion retail experiences and produce user-generated fashion garments, both digital as well as physical. Särämäkari and Vänskä (2022) argue that this has resulted in the emergence of a new type of designer, enmeshed with technologies and complex human networks: the “cyborg designer.” The digitalization of fashion heritage, which has taken the shape of digital archives and collections with 3D (motion) captured garments, has produced free and open access to fashion heritage (Melchior, 2019; Pecorari, 2019). Finally, highly rendered digital (re)presentations of fabric can communicate online tactile

information (Jang & Ha, 2023), such as fur and leather (Adegeest, 2023; van Raak, 2022). These are just some examples of how the advancement of digital technologies creates new forms of fashion 4.0, transforming or expanding traditional notions of the fashion system.

Virtual Worlds and Dressing Avatars

When we consider digital fashion as an object of study, we must first look at the space in which it exists: cyberspace, or more specifically, virtual worlds. Virtual worlds are defined as “persistent online computer-generated environments where multiple users in remote physical locations can interact in real-time for the purposes of work or play” (Dionisio et al., 2013, p. 1). They are a subset of virtual reality, a term used for computer-generated simulations of three-dimensional objects or environments with seemingly real, direct, or physical user interaction. The history of virtual worlds is one of literary imagination and gaming innovations that have led to open-ended, socially oriented virtual platforms. The advances of the Internet, virtual and digital representation through avatars had cultural and mediating effects on the fashion industry (Crewe, 2013; Dionisio et al., 2013). We argue that the emergence of virtual worlds, and subsequently that of the Internet and avatars, pioneered virtual fashion.

The late 1980s saw the birth of the earliest documented, digitally created virtual world with the videogame *Habitat*, originally released on the Commodore 64 in 1987. Not only was *Habitat* one of the pioneering high-profile commercial applications of virtual world technology and one of the first virtual worlds to incorporate a graphical interface, but it was also the earliest documented virtual world to employ the term “avatar” (Dionisio et al., 2013). In this two-dimensional virtual world, the term avatar was used to describe a transition from a human body to a digital representation, signaling an early awareness of human-avatar relations. While the avatars in *Habitat* wore clothes, they were far from the virtual clothes adopted in later virtual worlds.

From the mid-1990s onwards, virtual worlds started developing at a more rapid pace, mainly because of progress made in computing power and graphics. These new developments afforded the introduction of three-dimensional graphics, user-based content creation, and open-ended socialization in 3D spaces (Dionisio et al., 2013). Virtual worlds have evolved from being modeled solely after video games, like *Habitat*, to becoming spaces where users can express themselves through their avatars, interact with others, and engage in unique cultures. Virtual worlds rely heavily on Internet technologies by bringing together online users from all over the world in a virtual 3D environment. As such, it became more important for online users to dress and style their avatars. As the avatar became the digital representation of individual users online, virtual appearance was the first way of communicating and presenting the self to others (Zimmermann et al., 2022).

The year 2003 saw the emergence of *Second Life*, one of the most well-known and successful virtual worlds of the early 2000s. Much like any other virtual world that provides its users with clothes, accessories, and bodily customization, in *Second Life* users distinguish themselves from others through dress. *Second Life* has become a space and tool for identity building, self-expression, and community forming, as well as for venturing into business activities (Parmentier & Rolland, 2009). Through its marketplace, users could sell a variety of products and services, including hairstyles, accessories, apparel, bodily modifications, and so on, and earn real-life money. The success of *Second Life* in the early 2000s fostered a virtual economy built on the desire to (re)present oneself in virtual spaces.

Fashion E-commerce: The Internet and Social Media

The late 1990s saw the beginning of the World Wide Web, or Web 1.0. During these years, e-commerce activities returned to the fashion industry, much improved and more accessible than in the 1980s and early 1990s. As a result, e-commerce activities stabilized, became “normalized” and less erratic, but also laid the foundations for online activities to be integrated into the fashion industry

(Crewe, 2013). Web 1.0 is characterized as “read-only”; online users had no way of contributing. This changed from the 2010s onwards, as Web 1.0 developed into Web 2.0, which is characterized as “read and write.” This shift led to a major redefinition of the fashion industry, driven mostly by the rise of social media (Choufan, 2022; Crewe, 2013; Kawamura, 2023; Rocamora, 2013). Perhaps most radical is the transformation of fashion consumers from recipients or interpreters into active players; consumers became a crucial part of the process of value creation itself (Crewe, 2013). This collaborative nature and inclusion of user-generated content is what distinguishes Web 2.0 from Web 1.0. The use of social media as a democratic tool allows anyone to “freely produce, reproduce, adopt, spread, acknowledge, and/or reject fashion” (Kawamura, 2023, p. 65).

The post-Internet era of today is characterized by the speeding up of the circulation of material and symbolic goods (Rocamora, 2013). Goods are transferred almost immediately, which results in an economy favoring speed and quantity over quality. This increase in speed means that fast fashion has changed into even faster or “instant fashion” (Rocamora, 2013, p. 74). Social media and the Internet have changed fashion communities into “always-on” or “always-connected” communities, meaning that without social media or the Internet, physical bodies are isolated (Crewe, 2013).

The brief overviews of virtual worlds and the growing presence of the fashion industry on the Internet and social media illustrate that, for digital fashion to exist, there first needed to be a space for it; a space where digital fashion could be worn but also sold. In the next section, we explain how fashion and videogames have entangled themselves to the point that they have become inseparable.

Fashion and Play: Fashion in/as Videogames

Fashion scholars and journalists generally agree that many aspects of digital fashion were formed through videogame practices (Malget, 2022; McDowell, 2022; Sedin, 2022; Stuart, 2023). Creating an avatar, designing clothes, and dressing up one’s avatar are staple ingredients in modern videogames. As videogames have become ubiquitous media, the possibilities of expressing oneself in virtual environments grow more evident (Park & Chun, 2023). Rather than mapping this history in a linear manner, we look at several key moments in which fashion has been incorporated in videogames.

One of the earliest examples of a videogame centered around fashion is *Barbie Fashion Designer*, released in 1996 for the personal computer. In this game, players dress up Barbie by selecting clothes, accessories, colors, and pre-designed patterns to create an outfit. Barbie would then model the outfit on a 3D runway. Accompanying the videogame was a set of paper-backed fabric with markers and fabric paint so that players could print the designs and decorate them to dress their Barbie dolls. While *Barbie Fashion Designer* was more of an added experience of playing with Barbie dolls, it had an immense influence on the drag-and-drop dress-up browser games popularized in the 2000s and early 2010s after widespread adoption of Adobe Flash in the videogame industry (Reeves, 2018). Although Adobe Flash was discontinued in 2021, dress-up videogames are still being developed, with Nintendo’s *Style Savvy* franchise series being one of the most well-known examples. In these games, players take on the role of operating a boutique and coordinating outfits. Its latest installment, *Fashion Dreamer* (2023), enhances this formula by turning the player into a fashion influencer, which is more aligned with the fashion discourse of the 2020s. By garnering likes within the game, players unlock new items that they can use for styling new outfits. While in the genre of dress-up videogames the focus is exclusively on the act of dressing up, throughout the decades other genres of videogames have incorporated dressing up increasingly as secondary or complementary gameplay.

One example of a genre that does not focus on dress per se but incorporates it into the gameplay is the massively multiplayer online role-playing game or MMORPG. These are online videogames in

which players take up a particular role, often within a (fantasy) story, to participate with a very large number of players simultaneously. MMORPGs emphasize role-playing elements, character development, and storytelling within the broader framework of an online videogame. Dressing up your character in virtual clothing and accessories is central to the gameplay as it provides players with a sense of building their own story's protagonist. *World of Warcraft (WOW)* is perhaps the most well-known MMORPG, first released in 2004 and with downloadable content (DLC) still being released in 2024. In MMORPGs, players dress their characters with either functional gear to enhance gameplay by providing, for example, extra health or strength, or decorative gear for aesthetic purposes. Both types of gear are visible to other players and can sometimes confer prestige. Even if a player is indifferent to fashion, they prioritize obtaining the most powerful or protective armor pieces – in *WOW* this is called “best in slot” – to maximize their success in combat or quests. Acquiring this top-tier gear typically requires significant time and effort in the game. Similar to *Second Life*, in MMORPGs such as *WOW*, players can trade with each other, craft unique items, or obtain rare, event-exclusive items.

Videogame Skins

In its simplest sense, videogame “skins” are items or cosmetic changes with which a player can change their avatar's appearance. This can be a virtual outfit, an accessory (such as a weapon or armor), or the complete appearance of a character. Skins are either bought or won, and they typically communicate the status of the character/player (Särmäkari, 2023, p. 108n1). Generally, videogame skins are purely cosmetic and do not affect gameplay.

One of the earliest examples of videogame skins dates to February 1996, four months before the initial release of *Quake* in June 1996. Before its full-game release, developer id Software released a limited demo version of the game, accompanied by the game engine. The Quake engine fleshed out 3D environments that made it possible to create more detailed and complex virtual environments, moving beyond the simple and blocky designs that characterized videogames up until that point (Schreiner & Von Mammen, 2021). Players who had access to the engine were able to modify the videogame, adding new gameplay including replacing the player's default skin with custom designs.

The success of player-made videogame skins made game developers aware of the need for customizability in videogames. One of the earliest developer-made videogame skins was the “Horse Armor Pack” introduced in *Elder Scrolls IV: Oblivion* (released in 2006). This DLC (downloadable content) sold for \$2.50, allowed players to equip any owned horse with a set of protective armor. In today's terms, such a small selling price for in-game items would be called a “microtransaction.” The Horse Armor Pack was a topic of controversy at the time, especially because the game was single-player, yet it became a big success and set the precedent for microtransactions in free-to-play mobile games (Hernandez, 2022).

Several videogames have contributed to the widespread popularization and commercialization of videogame skins, specifically within two genres: MOBA (Multiplayer Online Battle Arena) and Battle Royale. In both genres, players select a pre-designed character out of a roster for each time they play. Videogame skins are, therefore, the only form of customization in the genres. Perhaps the best-known MOBA game is *League of Legends* (released in 2009), which today features 162 playable characters (“champions”) with their own abilities, pre-designed behavior patterns, gameplay, and set of skins that can be bought or in rare cases won. A famous example of a Battle Royale game is *Fortnite* (released in 2017), featuring over 1500 skins. Each skin represents a different character, without any change in gameplay, ranging from original creations to characters from popular culture such as *Marvel*, *Star Wars*, and *Dragon Ball*, but also real people like singer Ariana Grande or actor Keanu Reeves. While both games are free-to-play, they make their money mostly by charging players for in-game purchases (DLC and microtransactions) such as these cosmetic videogame skins. DLCs and microtransactions have become a staple business model in the

videogame industry, with DLCs being 24% and microtransactions 21% of gaming business models used by game developers worldwide in 2024 (Statista, 2024).

The videogame skin market took off in 2011 with the introduction of *Steam Trading*, which allowed online players using digital videogame distribution platform *Steam* to trade virtual in-game items between each other (Meyer, 2011). This had a significant impact on two particular videogames, *Counter-Strike: Global Offensive* (released in 2012) and *Team Fortress 2* (released in 2007), both first-person shooter games. Not only were skins used as rewards for winning in-game, but gradually online communities emerged that engage in skin gambling, using skins as virtual currency to gamble on professional matches or other gambling games. Today, videogame skins play a pivotal role in the videogame industry, not only in terms of added gameplay but also financially.

Players Become Designers

Videogames also incorporate creating custom outfits that an avatar can wear during the main gameplay. An interesting example is the *Animal Crossing* franchise, a series of sandbox games, which are open-world videogames that allow players a high degree of freedom and autonomy. In the case of latest installment *Animal Crossing: New Horizons* (ACNH), released in 2020 at the beginning of the COVID-19 pandemic, players live on a secluded island where they can choose between a variety of activities such as catching fish and bugs for the museum, building houses and stores, and creating custom patterns. These patterns are composed of a 32 by 32 pixels grid that can be colored using a customizable pallet of colors. The finished patterns can be displayed on a surface such as a wall or ground but can also be used for creating custom outfits. ACNH provides several garment types (tops, dresses, and headwear) made up of multiple grids that enable the player to create more complex designs and combine different patterns, for instance, unique patterns for the front, back, and each sleeve of a sweater. Each custom outfit or pattern can be shared between users through QR codes. Instagram served as one of the main channels for disseminating these codes (Renault, 2023). Pattern-making custom outfits in ACNH increased the experience of personalization and identity expression. As Sophie Renault writes, “creating, sharing and collecting designs represents a form of appropriation and enrichment of the video-game experience. [...] [M]erged with their avatar, the player feeds the video game database and thus participates in its value creation system” (2023, p. 177). Videogaming in the social media era is characterized by this ability to create, wear, showcase, and even sell personalized garments globally.

Fashion Brands and Videogames: “Advergames”

So far we have seen that fashion in videogames involves dressing up one’s avatar as well as creating dress, both of which result in a more personalized gaming experience. The personalized relationship between fashion and videogames, and the huge success of videogames have not escaped the fashion industry. Fashion brands have therefore added videogames to photography and film as forms of communication tools. While fashion brands Adidas and Burberry were considered frontrunners in the digitalization of fashion at the beginning of the millennium (Crewe, 2013; Mattila, 2016), today many of the larger luxury and fast fashion brands have delved into the digital realm of videogames to create virtual clothing. Memorable collaborations include Moschino and *The Sims*; H&M and *Animal Crossing*; Balenciaga and *Fortnite*; and Burberry and *Minecraft*.

Take, for example, luxury fashion brand Louis Vuitton, whose endeavor into digital fashion includes (but is not limited to) two pioneering campaigns. In 2015, Louis Vuitton collaborated with developer Square Enix and their videogame *Final Fantasy XIII* (first released in 2009) for their S/S 2016 collection “SERIES 4.” Labelled as the “virtual heroine,” *Final Fantasy XIII*’s main protagonist Lightning was featured as one of the models in the campaign’s advertisements (Louis

Vuitton, 2015). Lightning was styled in several outfits and carrying several of Louis Vuitton's iconic bags, which were later showcased physically on the catwalk. In 2019, Louis Vuitton extended its presence in the videogame industry by entering a multi-year deal with *League of Legends*, which up until today has resulted in both physical and digital products. In terms of digital garments, Louis Vuitton has created limited-edition videogame skins for several champions to be worn in-game (Oloman, 2021).

The COVID-19 quarantine saw an increase in videogame usage. Harry Chen argues that during the pandemic, online videogames became a more widespread means of psychological and social communication in society (Chen, 2022). Fashion brands jumped on the bandwagon and increasingly collaborated with videogame developers to realize in-game clothing. While in some cases the items are digital twins of physical clothing or *phygital fashion*, fashion brands have also collaborated to create digital-exclusive clothing items.

Fashion brands have even ventured into creating videogames themselves. Different from in-game advertising, these so-called "advergames" are strategies in which a fashion brand collaborates with the game industry to induce voluntary engagement and immersion among users, with the main objective of creating positive associations with the brand and increasing purchase intention among consumers (Park & Chun, 2023). In this sense, players can engage with the fashion brand and become potential consumers.

Early advergames are found on the social network platform Facebook, which has featured games on its platform since the mid-2000s. Brands and companies used Facebook mainly as marketing environment, combining entertainment with advertisements (Ayada & Elmelegy, 2012). Fashion brands featured their designs as purchasable in-game items, but also with the option to purchase the corresponding physical item, and as such displayed two prices accordingly.

Fashion brands seized the growing adoption of smartphones and the subsequent development of the mobile videogame industry by creating advergames for mobile phones. In *LOUIS: The Game*, released in 2019 to celebrate Louis Vuitton's 200th birthday, virtual mascot Vivienne explores several of the major fashion cities such as London and Paris. Throughout the game, players learn about Vuitton's history and are rewarded with digital NFT collectibles of Vuitton's most iconic products (Showstudio, 2021). With over two million downloads *LOUIS: The Game* proved a highly successful advergame. Eight months after its initial release, additional content and collectibles were added. This second chapter of the game is only accessible after finishing the first and adds more information to the brand's history (McDowell & Shoab, 2022; Showstudio, 2022).

Another acclaimed advergame is Balenciaga's *Afterworld: The Age of Tomorrow*, unveiling their A/W 2021 collection. Players embark on a hero's journey that starts in a Balenciaga store, moving through a futuristic city to a secret forest rave, and ending atop a mountain (Balenciaga, 2020). Throughout the story, players encounter different avatars adorned in Balenciaga's new collection. In both *LOUIS* and *Afterworld*, the fashion brands have integrated digital fashion items as "visual cues" of the brand's identity or collection, providing engagement to players/consumers in the form of voluntary play (Park & Chun, 2023). *LOUIS* and *Afterworld* show how high-end brands moved from videogames towards practices such as NFTs and the Metaverse, commonly attributed to Web 3.0.

The Digital Fashion Industry

Web 3.0 and NFTs

In recent years, major fashion brands and companies have started exploring possibilities of digital fashion outside the gaming sphere (Särmäkari, 2023). In this section, we discuss Web 3.0 and the digital technologies characterizing it, such as the Metaverse, blockchains, cryptocurrency, and NFTs. The term Web 3.0 was coined in 2014 by computer scientist Garvin Wood, six years after the creation of Bitcoin. Wood, founder of blockchain platform Polkadot and co-founder of the Ethereum cryptocurrency described Web 3.0 as "a decentralized online ecosystem based on the blockchain" (Edelman, 2021). Web 3.0 can be best understood as a response to the issues and concerns

regarding privacy, censorship, centralization, financial exclusion, and lack of ownership in Web 2.0 (Stackpole, 2022). In Web 3.0, online users are not producers (of data), but owners, which is realized through blockchain systems and cryptocurrency. Furthermore, the online nature and worldwide accessibility of Web 3.0 facilitates participation beyond Western brands and companies, enabling brands, companies and independent designers from diverse geographic regions and smaller-scale operations to also engage and contribute within these virtual environments. While the earliest documented NFT was already bought or “minted” in 2014, 2019 featured the first recorded sale of a digital fashion garment on the blockchain. This was the “Iridescence” dress by digital fashion house The Fabricant which was sold for \$9500 worth of cryptocurrency (Särmäkari, 2023; The Fabricant, 2019).

Fashion in the M/metaverse

For several years there has been a widespread and growing interest from brands in NFTs and Web 3.0 technologies as promising ways of engaging customers in the Metaverse. The Metaverse, a portmanteau of the prefix “meta” (meaning ‘beyond’) and the suffix “-verse” (from “universe”), refers to the futuristic concept of a computer-generated, three-dimensional world that is characterized by immersive realism, ubiquity of access and identity, interoperability, and scalability (Dionisio et al., 2013). The term was already coined in 1992 in the sci-fi novel *Snow Crash* by Neal Stephenson. In terms of historical developments, the goal of achieving the Metaverse has brought forth the latest development of virtual worlds that started in 2007 (Dionisio et al., 2013). The Metaverse is an amplified, large network of interconnected virtual worlds that functions on interoperability; the idea that digital goods can be shared and transferred between virtual worlds. For digital fashion, this means being able to wear the same digital garment in different virtual environments. As of today, the futuristic concept of the Metaverse has not yet been achieved, mostly because of a lack of universal cross-platform compatibility (Dionisio et al., 2013; Ravenscraft, 2023).

The last two decades have seen the emergence of a plurality of platforms trying to achieve the status of Metaverse. These virtual worlds, mostly but not always utilizing blockchain systems, cryptocurrency, and NFTs, are commonly referred to as “a metaverse” (non-capitalized). Well-known examples include *Minecraft* (2009), *Roblox* (2006), Meta’s *Horizon Worlds* (2019), *Decentraland* (2020), and *ZEPETO* (2018). What makes something a metaverse instead of simply a videogame is ambiguous. Each of these metaverses is different in immersion, interoperability, scale, and access, and holds unique ways of social interaction that can be utilized in different ways such as education, socialization, work, or organizing events.

In terms of fashion, these metaverses have been explored quite differently in recent years. For example, Gucci has partnered with *Roblox* to create different immersive experiences. For Gucci’s 100th birthday, they created Gucci Garden (accessible from May 17 to 31, 2021), a virtual environment that mimicked Gucci’s Gucci Garden Archetypes, an immersive multimedia experience in the city of Florence (Roblox, 2021). As users enter the virtual environment and explore different rooms, their avatar turns into a neutral, featureless mannequin that will absorb elements of the exhibition, with each avatar ultimately unique in appearance. While this environment was accessible for only two weeks, it received over twenty million visitors. In May 2022, Gucci and *Roblox* collaborated once more to create a persistent virtual environment: Gucci Town, consisting of various areas all connected to a central garden (Webster, 2022). Users can socialize with one another, play mini-games, and shop virtual wearables by Gucci for their avatars.

Virtual Influencers

Another facet of Web 3.0 involves social media and influencers, more specifically virtual influencers. Virtual influencers are computer-generated virtual personas that serve marketing purposes and are

mostly active on social media and video-sharing platforms. While virtual influencers emerged a decade earlier, they assume an important role in shaping public opinion and behavior in digital markets including Web 3.0. Fashion campaigns, photos and videos, are increasingly created to share on social media platforms (Choufan, 2022). Virtual influencers take an active part in this “sharing of fashion,” as models or brand ambassadors wearing a brand’s digital fashion, with the ultimate goal of promoting certain lifestyles and (digital) assets.

One of the earliest virtual influencers is Lu do Magalu (Lu of Magalu), who was created in 2009 by Brazilian Magazine *Luiza*. Lu appears on digital platforms such as TikTok, Instagram, YouTube, and X (formerly Twitter) for promotional activities. A decade after Lu’s creation, there is a marked increase in and diversification of virtual (fashion) influencers. For example, Shudu is a Black South African virtual influencer who was created in 2017 by digital modeling agency The Diigitals. She is one of the first digital supermodels, having worked with Paco Rabanne, Louis Vuitton, *Harper’s Bazaar*, *Vogue*, and *Cosmopolitan*. Another recent example by the Diigitals is Kami, the first virtual influencer with Down Syndrome, introduced in 2022 (Rasmussen, 2022). In 2019, Calvin Klein featured Bella Hadid and virtual influencer Lil Miquela (also known as Miquela Sousa) in a 35-s video for their “I Speak My Truth in #MyCalvins” campaign. This video, posted on Lil Miquela’s YouTube account, has received almost 700.000 views on YouTube, showcasing a hybrid fusion of physical and digital worlds.

Digital Fashion During the Pandemic

The years 2019 to 2022 saw significant proliferation and acceleration for the digital fashion industry. The main reason was the COVID-19 pandemic that confined a large part of the world’s population to their homes. People interacted with each other mostly through their devices and shopped for clothes mostly online through the Internet. This led to the launch and growth of several virtual services. Earlier we mentioned the “virtual closet” website DressX launched in 2020, where users can purchase image and video-based NFTs and superimposed images (digital garments photoshopped onto one’s own image). Their AR app followed in 2021, allowing users to wear their digital fashion in real-time through AR filters. Driven by a need to break away from the fast fashion system, their vision is “Don’t shop less, shop digital fashion” as a response to the growing surge of online apparel shopping during the pandemic. In 2024, DressX is one of the biggest digital fashion retailers, if not the biggest, featuring collaborations with over 400 designers.

The pandemic also brought new possibilities for fashion magazines. In 2021 *Vogue Singapore* collaborated with virtual artists and 3D fashion designers to create two digital-only NFT covers for their issue titled “New Beginnings” (Zhao, 2021). By scanning the QR code on the (digital) cover, readers were transported to a virtual environment where they could access the NFT auction, try out AR filters on Instagram, and find videos and articles on *Vogue Singapore*’s endeavors in Web 3.0.

For physical luxury and fast fashion brands, the pandemic initially had negative effects, which prompted the brands to experiment and venture into collaborations with highly successful digital fashion houses and designers. Together, they created capsule collections announcing their virtual presence. One such example is H&M’s collaboration with the Institute of Digital Fashion (IoDF) in 2022. This collaboration featured a capsule collection of both digital and physical garments. Inspired by circularity and eco-fashion, H&M and IoDF created five digital AR garments that take the tactile aesthetics of the natural world as a reference point, including satellite images of Earth, images of microscopic cells, and vibrant wildflowers (H&M, 2022). In other cases, there have been mergers of companies, such as the purchase of virtual sneakers and NFT collectibles organization RTFKT by NIKE in 2021. This purchase was significant as it not only established NIKE’s presence in the digital fashion industry, but also highlighted that physical fashion brands were ready to acknowledge the potential of digital fashion.

Between the periods of quarantine, digital fashion found its way into the museum sector. In the Netherlands, several museums and art exhibition spaces featured digital fashion. For example, the Design Museum in Den Bosch presented “Screenwear – Exploring Digital Fashion” (2022), an exhibition on digital fashion from its early beginnings to the latest trends including most memorable collections. The interest in digital fashion outside the fashion domain is an early indication of the social and cultural impact of digital fashion.

As the pandemic impeded physical fashion events, such events as the seasonal Fashion Weeks had to migrate to the digital space. Some did so through livestreaming on social media, whereas others moved towards metaverses and videogames. By now, several annual and seasonal events have emerged that are exclusively dedicated to digital fashion, such as Metaverse Fashion Week (MVFW), hosted in *Decentraland*. In this metaverse users can socialize, play games, and own clothing and accessories, but also buy, own, and build on virtual land. First organized in 2022, MVFW is an annual event celebrating digital fashion, featuring a range of activities from presenting, buying, selling, making, and giving away digital fashion, to holding panels, games, workshops, and afterparties. Major (digital) fashion brands work together with *Decentraland* and host their virtual wearables in virtual exhibition spaces where users can view and purchase clothing and accessories for their avatars. Yet, physical fashion brands did not completely halt the production of their physical clothes. While some brands like Adidas and Tommy Hilfiger released digital-exclusive garments that visually looked very different from their physical garments, other brands promoted their physical fashion at digital events using digital twins (digital representations of their physical garments).

Artificial Intelligence: The Future of Digital Fashion?

The year 2023 saw an explosive growth in public interest in and adoption of artificial intelligence, including in the fashion industry. One of the earliest digital fashion collections to utilize generative AI is The Fabricant’s *Deep* collection, designed by Amber Jae Slooten in 2017 and re-released as NFTs in 2023. This collection used images from Paris Fashion Week to algorithmically generate designs that were then translated into 3D animations. The collection features seven designs, showing “hyperreal visualizations of a complete fashion collection, without the collection ever existing in real life” (The Fabricant, 2017).

Other brands and designers have also explored the potential of AI in digital fashion design. In April 2023, the very first edition of AI Fashion Week took place. This global event, which was set up as a competition, featured over 400 submissions of algorithmically generated fashion collections, of which ten were selected by a public vote. Out of these ten collections, three winners were selected by a panel of industry experts and were awarded a partnership with Revolve to produce a collaborative collection that was featured at the second edition of AI Fashion Week in November 2023 (Garcia-Furtado, 2023).

In terms of fashion retail, AI is mostly used to improve retail experiences and provide purchase recommendations. In June 2023, Google rolled out its new AI-powered, virtual try-on tool. This new tool, accessible in Google search, makes it possible to see how shoppable items look on a range of models. Google photographed forty men and forty women to capture a range of sizes (from XXS to 4XL), body shapes, ethnicities, hairstyles, and skin tones. Through artificial intelligence, the items that online shoppers want to buy can be digitally portrayed on the model’s still image (McDowell, 2023). Google’s virtual try-on technology is still in an early phase and not yet globally accessible but will hopefully consider the diversity of human bodies. Through its generative AI, the technology will develop, learn, and improve as it gets used by consumers.

Yet, AI adoption is not always without backlash. In mid-March 2023, Levi Strauss & Co. announced a partnership with digital fashion house Lalaland.ai to create AI-generated models for Levi’s e-commerce platform. These models were intended to supplement human models by

representing diverse body types, ages, sizes, and skin tones. However, the partnership sparked criticism, particularly over concerns about the potential replacement of human models, especially models of color, and the broader ethical implications of using AI in fashion (LS&Co., 2023). The backlash prompted LS&Co. to issue an official apology.

Concluding Remarks

It is clear from its short and uneven history that digital fashion has become a rich and complex field far removed from the simplistic fantasy of *Chueless*. We have explained that digital fashion is digital-born and digital-only fashion; unlike material clothes, its end products are created digitally for digital use. We have traced the emergence and development of digital fashion through virtual worlds, the implementation of avatars and fashion in videogames, and finally the commercially led digital fashion industry that has emerged in the past few years under the umbrella term Web 3.0. We have discussed a range of examples in the development of digital fashion: digital skins for gamified environments, digital skins for virtual influencers, superimposed images, Augmented Reality filters, NFTs (Non-Fungible Tokens), and digital twins, or *phygital* fashion. Finally, we have touched upon the most recent developments in the use of artificial intelligence for digital fashion and the fashion industry.

The trajectory of digital fashion is marked by innovation and exponential growth. It took decades for the fashion industry to establish itself online, despite its close relationship to technological developments. Yet, once fashion found its digital place, it quickly developed across virtual worlds, videogames, social media, and into our daily mediated online lives. This history demonstrates a departure of digital fashion from traditional notions of dress, from transcending its physical constraints to embracing the digital-only nature of virtual realms. Digital fashion has evolved from its humble beginnings in virtual worlds into a multifaceted domain spanning a broad range of mediums and technologies. We examined the progression of digital fashion over time to demonstrate that the industry evolved gradually, rather than appearing suddenly.

Further research on digital fashion can build upon the historical context outlined in this article. Given the rapid pace in which digital fashion is developing, it requires continuous examination and exploration of different methodologies and frameworks, such as interviews and Actor-Network-Theory. Additionally, future studies could investigate how digital fashion has influenced, shaped, or impacted the design, production, and wearing of fashion in the physical world.

To conclude, we want to point out that digital fashion underscores a symbiotic relationship between technology and creativity. In our view, advancements in artificial intelligence may revolutionize the intricate connection between digital fashion and creative design. However, as the Levi's example illustrates, this demands careful ethical consideration. In this article, we have shown that the history of digital fashion shows promising development and experimentation, bringing the fashion industry toward new frontiers of creation, production, and consumption.


Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Adil Boughlala  <https://orcid.org/0000-0002-6254-4404>

Notes

1. We use the term “digital fashion” instead of similar but different terms such as “virtual fashion,” “digital apparel,” and “Metaverse fashion” because digital fashion serves as an inclusive umbrella term that is more widely used in academia and the fashion industry.
2. The museum visits included Design Museum, Den Bosch; NXT Museum, Amsterdam; Centraal Museum, Utrecht; and Felix Meritis, Amsterdam. The digital events included Metaverse Fashion Week in *Decentraland* as well as several immersive brand experiences by (digital) fashion brands that took place across various metaverses. We have also visited Digital Fashion Week physically in Milan. These visits were done over the course of Summer 2022 and Summer 2024.

References

- Adegeest, D.-A. (2023, November 10). *Student design competition takes leather from the Real World to the Virtual Realm*. FashionUnited. <https://fashionunited.uk/news/business/student-design-competition-takes-leather-from-the-real-world-to-the-virtual-realm/2023111072528>
- Amed, I., Balchandani, A., Berg, A., Altable, C. S., Harreis, H., Petersens, S. a., Roberts, R., Kersnar, J., Hurtado, M., Bain, M., & Crump, H. (2022). *The state of fashion technology 2022 (state of fashion)*. The Business of Fashion and McKinsey & Company.
- Ayada, W. M., & Elmelegy, N. A. (2012). Advergaming on Facebook a new approach to improve the fashion marketing. *International Design Journal*, 2(2), 139–151.
- Balenciaga. (2020). *Fall 21 Press Release*. Balenciaga. <https://videogame.balenciaga.com/en/press>
- Berg, A., Hedrich, S., Lange, T., Magnus, K.-H., & Mathews, B. (2017). *The apparel sourcing caravan's next stop: Digitization (McKinsey Apparel CPO Survey 2017)*. McKinsey Apparel, Fashion & Luxury Group.
- Bertola, P., & Teunissen, J. (2018). Fashion 4.0 innovating fashion industry through digital transformation. *Research Journal of Textile and Apparel*, 22(4), 352–369. <https://doi.org/10.1108/RJTA-03-2018-0023>
- Casini, L., & Rocchetti, M. (2020). Fashion, Digital Technologies, and AI. Is the 2020 Pandemic Really Driving a Paradigm Shift? *ZoneModa Journal*, 10(2). <https://doi.org/10.6092/ISSN.2611-0563/11802>
- Chan, H. H. Y., Henninger, C., Boardman, R., & Blazquez Cano, M. (2024). The adoption of digital fashion as an end product: A systematic literature review of research foci and future research agenda. *Journal of Global Fashion Marketing*, 15(1), 155–180. <https://doi.org/10.1080/20932685.2023.2251033>
- Chen, H. (2022). The impact of the COVID-19 on the video game market. In F. Balli, A. Y. H. Nee, & S. A. Qalati (Eds.), *Proceedings of the 2022 international conference on economics, smart finance and contemporary trade (ESFCT 2022)* (Vol. 226, pp. 70–78). Atlantis. https://doi.org/10.2991/978-94-6463-052-7_9
- Choufan, L. (2022). Fashion you do not own, fashion you cannot feel: Toward a new paradigm of sharing fashion in the digital age. *Fashion Theory*, 26(3), 307–328. <https://doi.org/10.1080/1362704X.2021.1912954>
- Crewe, L. (2013). When virtual and material worlds collide: Democratic fashion in the digital age. *Environment and Planning A*, 45, 760–780. <https://doi.org/10.1068/a4546>
- Dionisio, J. D. N., Burns, W. G., III, & Gilbert, R. (2013). 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Computing Surveys*, 45(3), 34:1–34:38. <https://doi.org/10.1145/2480741.2480751>
- Edelman, G. (2021, November 29). *The Father of Web3 Wants You to Trust Less*. Wired. <https://www.wired.com/story/web3-gavin-wood-interview/>
- The Fabricant. (2017). *Deep / The Fabricant*. <https://www.thefabricant.com/deep>
- The Fabricant. (2019). *Digi-couture: Iridescence*. <https://www.thefabricant.com/iridescence>
- Garcia-Furtado, L. (2023, April 24). *At AI Fashion Week, Human Creativity Remains the Focus*. Vogue. <https://www.vogue.com/article/ai-fashion-week-designers>
- Heckerling, A. (Director). (1995). *Clueless [Video recording]*. Paramount Pictures.
- Hernandez, I. (2022, October 13). Horse armor was mocked, but it launched a billion-dollar cosmetic industry. *Polygon*. <https://www.polygon.com/23399591/elder-scrolls-4-oblivion-horse-armor-video-game-cosmetics>

- H&M. (2022, November 17). *A metaverse design story*. H&M Magazine. https://www2.hm.com/it_it/life/culture/inside-h-m/metaverse-design-story.html
- Jang, S. Y., & Ha, J. (2023). Presenting fabrics in digital environment: Fashion designers' perspectives on communicating tactile qualities of the fabrics. *Fashion and Textiles*, 10(6). <https://doi.org/10.1186/s40691-022-00328-2>
- Kawamura, Y. (2023). *Fashion-ology: Fashion studies in the postmodern digital era* (3rd ed.). Bloomsbury.
- Louis Vuitton. (2015, January 6). *Series 4: Lightning – A Virtual heroine*. <https://au.louisvuitton.com/eng-au/articles/series-4-lightning-a-virtual-heroine->
- LS&Co. (2023, March 22). *LS&Co. Partners with Lalaland.ai*. Levi Strauss & Co. <https://www.levistrauss.com/2023/03/22/lSCO-partners-with-lalaland-ai/>
- Malget, F. (2022, February 23). *How games were an early entry point into the world of digital fashion*. FashionUnited. <https://fashionunited.com/news/fashion/how-games-were-an-early-entry-point-into-the-world-of-digital-fashion/2022022346044>
- Mattila, H. (2016, October 2). *Digital Fashion—How and When?* The 8th International Textile, Clothing & Design Conference – Magic World of Textiles (ITC&DC), Dubrovnik. <http://urn.kb.se/resolve?urn=urn:nbn:se:hb:diva-11048>
- McDowell, M. (2022, February 28). *It's not just gamers and crypto dudes buying digital fashion*. Vogue Business. <https://www.voguebusiness.com/technology/its-not-just-gamers-and-crypto-dudes-buying-digital-fashion>
- McDowell, M. (2023, June 14). *Google introduces virtual try-on using generative AI*. Vogue Business. <https://www.voguebusiness.com/technology/google-introduces-virtual-try-on-using-generative-ai>
- McDowell, M., & Shoaib, M. (2022, April 14). *Louis Vuitton to release new NFTs*. Vogue Business. <https://www.voguebusiness.com/technology/louis-vuitton-to-release-new-nfts>
- Melchior, M. R. (2019). Digital fashion heritage: Understanding europeanafashion.eu and the google cultural institute's we wear culture. *Critical Studies in Fashion & Beauty*, 10(1), 49–68. https://doi.org/10.1386/csfb.10.1.49_1
- Meyer, J. (2011, August 10). *New Steam Update Lets Players Trade Hats for Games*. Wired. <https://www.wired.com/2011/08/steam-trading-update/>
- Nobile, T. H., Noris, A., Kalbaska, N., & Cantoni, L. (2021). A review of digital fashion research: Before and beyond communication and marketing. *International Journal of Fashion Design, Technology and Education*, 14(3), 293–301. <https://doi.org/10.1080/17543266.2021.1931476>
- Oloman, J. (2021, July 12). *Gaming is entering its fashion-forward phase*. Washington Post. <https://www.washingtonpost.com/video-games/2021/07/12/video-game-fashion-esports-streetwear/>
- Pal, K., & Yasar, A.-U.-H. (2020). Internet of things and blockchain technology in apparel manufacturing supply chain data management. *Procedia Computer Science*, 170, 450–457. <https://doi.org/10.1016/j.procs.2020.03.088>
- Papahristou, E., Kyratsis, P., Priniotakis, G., & Bilalis, N. (2017). The interconnected fashion industry—An integrated vision. *IOP Conference Series: Materials Science and Engineering*, 254. <https://doi.org/10.1088/1757-899X/254/17/172020>
- Park, J., & Chun, J. (2023). Evolution of fashion as play in the digital space. *Fashion Practice*, 15(2), 256–278. <https://doi.org/10.1080/17569370.2022.2149837>
- Parmentier, G., & Rolland, S. (2009). Consumers in virtual worlds: Identity building and consuming experience in second life. *Recherche et Applications En Marketing (English Edition)*, 24(3), 43–55. <https://doi.org/10.1177/205157070902400302>
- Pecorari, M. (2019). Fashion archives, museums and collections in the age of the digital. *Critical Studies in Fashion & Beauty*, 10(1), 3–29. https://doi.org/10.1386/csfb.10.1.3_7
- Rasmussen, M. (2022, May 24). *Kami is the First Virtual Influencer with Down Syndrome*. <https://www.virtualhumans.org/article/kami-is-the-first-virtual-influencer-with-down-syndrome>
- Ravenscraft, E. (2023, June 15). What Is the Metaverse, Exactly? *Wired*. <https://www.wired.com/story/what-is-the-metaverse/>

- Reeves, B. (2018, December 22). *How flash games changed video game history*. Game Informer. <https://www.gameinformer.com/2018/12/22/how-flash-games-changed-video-game-history>
- Renault, S. (2023). My avatar, fashion and me. *Décisions Marketing*, 109(1), 161–179. <https://doi.org/10.3917/dm.109.0035>.
- Roblox. (2021, May 17). *The Gucci Garden Experience Lands on Roblox*. Roblox Blog. <https://blog.roblox.com/2021/05/gucci-garden-experience/>
- Rocamora, A. (2013). New fashion times: Fashion and digital Media. In S. Black, A. de la Haye, J. Entwistle, A. Rocamora, R. A. Root, & H. Thomas (Eds.), *The handbook of fashion studies* (pp. 61–77). Bloomsbury.
- Rocamora, A. (2017). Mediatization and digital media in the field of fashion. *Fashion Theory*, 21(5), 505–522. <https://doi.org/10.1080/1362704X.2016.1173349>
- Rocamora, A. (2018). The labor of fashion blogging. In L. Armstrong & F. McDowell (Eds.), *Fashioning professionals: Identity and representation at work in the creative industries* (pp. 65–82). Bloomsbury.
- Rocamora, A. (2022). The datafication and quantification of fashion: The case of fashion influencers. *Fashion Theory*, 26(7), 1109–1133. <https://doi.org/10.1080/1362704X.2022.2048527>
- Särmäkari, N. (2023). Digital 3D fashion designers: Cases of atacac and the fabricant. *Fashion Theory*, 27(1), 85–114. <https://doi.org/10.1080/1362704X.2021.1981657>
- Särmäkari, N., & Vänskä, A. (2022). ‘Just hit a button!’ – fashion 4.0 designers as cyborgs, experimenting and designing with generative algorithms. *International Journal of Fashion Design, Technology and Education*, 15(2), 211–220. <https://doi.org/10.1080/17543266.2021.1991005>
- Schreiner, L., & Von Mammen, S. (2021). Modding support of game engines. *The 16th International Conference on the Foundations of Digital Games (FDG) 2021*, 1–9. <https://doi.org/10.1145/3472538.3472574>
- Schwab, K. (2017). *The fourth industrial revolution*. Penguin UK.
- Sedin, E. (2022, April 19). *Why is digital fashion so reliant on gaming?* Scandinavian MIND. [https://scandinavianmind.com\\$\(this.\\$route.fullpath\)](https://scandinavianmind.com$(this.$route.fullpath))
- Showstudio. (2021, October 3). *Louis Vuitton to Launch a Video Game Featuring NFTs by Beeple | SHOWstudio*. Showstudio. <https://showstudio.com/news/louis-vuitton-to-launch-a-video-game-featuring-nfts-by-beeple>
- Showstudio. (2022, April 19). *Louis Vuitton’s “Louis: The Game” Chapter Two Commences | SHOWstudio*. Showstudio. <https://showstudio.com/news/louis-the-game-chapter-two-commences>
- Stackpole, T. (2022, May 10). *What is Web3?* <https://hbr.org/2022/05/what-is-web3#:~:text=Advocates%20argue%20that%20Web3%20will,next%20era%20of%20the%20internet>
- Statista. (2024). *Most popular video game business models worldwide 2024*. Statista. <https://www.statista.com/statistics/1183087/game-developers-business-models/>
- Stuart, K. (2023, March 1). *Hot buttons: Why fashion houses are getting into video games*. The Guardian. <https://www.theguardian.com/games/2023/mar/01/why-fashion-houses-are-getting-into-video-games>
- Tortora, P. G. (2015). *Dress, fashion and technology: From prehistory to the present*. Bloomsbury.
- van Raak, P. (2022, June 13). *Fur fashion to fight the fur industry*. Mobiquity. <https://www.mobiquity.com/insights/fur-fashion-to-fight-the-fur-industry>
- Wang, W., Fang, Y., Nagai, Y., Xu, D., & Fujinami, T. (2020). Integrating interactive clothing and cyber-physical systems: A humanistic design perspective. *Sensors*, 20(1), 127. <https://doi.org/10.3390/s20010127>
- Webster, A. (2022, May 27). *Gucci built a persistent town inside of Roblox*. The Verge. <https://www.theverge.com/2022/5/27/23143404/gucci-town-roblox>
- Zhao, K. (2021, September 6). *Metaverse magic: Here’s your chance to own Vogue Singapore’s two September digital covers as NFTs*. Vogue Singapore. <https://vogue.sg/september-2021-digital-covers-nft/>
- Zimmermann, D., Wehler, A., & Kaspar, K. (2022). Self-representation through avatars in digital environments. *Current Psychology*, 42(25), 21775–21789. <https://doi.org/10.1007/s12144-022-03232-6>

Author Biographies

Adil Boughlala graduated with distinction from the Research Master's program in Art and Visual Culture at Radboud University Nijmegen. He was a visiting research student at ModaCult, Università Cattolica del Sacro Cuore in Milan. His research interests include fashion, visual media, and digital culture, having published on these topics as well.

Anneke Smelik is professor emerita of Visual Culture at the Radboud University Nijmegen. She has published widely in the field of fashion, cinema, popular culture and cultural memory. Among her books are *Thinking Through Fashion. A Guide to Key Theorists* and *Delft Blue to Denim Blue. Contemporary Dutch Fashion*. She is co-editor of the journal *Critical Studies in Fashion & Beauty*.