Chapter

Fashion: From 3D Printing to Digital Fashion[1]

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Abstract

Our scope is to emphasize the massive changes brought about by 3D and 4D printing in the fashion world (now connected with augmented reality and virtual reality) by addressing the concept of 3D printing and explaining when and how it started to develop in fashion, becoming the sewing machine of the twenty-first century. It has allowed for great changes in the fashion industry, namely the appearance of more sustainable, and customized apparel and accessories, simpler logistics and less transaction costs. This requires increased creativity, because it demands the cooperation of specialists from many different areas. New and before deemed impossible shapes have arisen. The final idea of prosumer and its meaning is before us. If we add 4D printing, that is, "intelligent" materials, 3D printing enters our day lives, with wearables and smart clothes. All this raises questions regarding copyright and industrial property protection and possible infringement in those areas. Current 4D products also raise questions regarding personal data protection. We will address how to protect intellectual property and personal data in this world of digital fashion, where augmented and virtual reality play a roll of increased importance.

Keywords: fashion law, 3D printing, 4D printing, augmented reality, virtual reality, metaverse; copyright, industrial property, personal data

1. Introduction

Three-dimensional (3D) printing includes several additive manufacture technics, toward a new era of production and consumerism, based on the "make it yourself," thus the expression prosumer (producer and consumer). Three-dimensional printing allows manufacture of apparel, wallets, footwear, and accessories on demand, near the distribution chains, lowering the costs of transport and storage. These fashion items can be almost immediately obtained and customized and achieve creative forms not possible before and in a much more sustainable way because there is almost no waist. Such technology exists for about 40 years but is always evolving and did not enter the fashion industry until 2009, when pioneer Dutch stylist Iris van Herpen started to use it in a regular basis. Before, plastic materials used in 3D were too stiff and inappropriate for fashion [1].

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What is common in 3D technique is the creation of a computer file with the desired shape (*Computer-Aided Design* file), which passes on to a 3D printer. The most used format of the CAD file is *.stl*. The file can be obtained by several means, namely by creating the object using 3D software, by 3D scanning an existing object, or using 3D sharing websites.

Three-dimensional printing is an additive manufacture technique, usually layer by layer, thus more sustainable with much less waist and costs. Today, almost all materials can be used, even biological ones, and the technique allows to recycle the 3D-printed apparel, footwear, wallets, and accessories, and even to reuse plastics that pollute the seas. 3D allows the user to customize any piece.

Four-dimensional printing (4D) is more recent, and it adds to the 3D technique the use of "intelligent" materials, programmed to adjust to the changing needs of the user, like hydrogel, polymers with memory shape (PMF), and liquid crystal elastomers (LCE). The difference between 3D and 4D has to do with the difference of materials. Three-dimensional (3D) uses traditional materials, while 4D uses pseudo-intelligent materials printed in 3D.

In the last years, 4D technology has been increasingly used in wearables and smart clothes. Examples include apparel and footwear that can adapt to the body of the user and can change with movement, adapt to possible impacts, temperature changes, among others. The Covid-19 pandemic led to very interesting solutions and, even more, accelerated the interest in totally digital fashion items.

Wearables and smart clothes use technology that offers the user new and distinct functionalities, making everyday life more practical [2]. Examples of wearables include: (a) wristbands that monitor exercise, linked to an app, allow, among others, to count the steps, and monitor heart rate, vital parameters, sleep cycles, and calories burned; (b) although more recent, sunglasses, pendants, earrings, and rings, which incorporate technologies are used as physical status trackers, stress managers, and step counters; (c) smart watches that, in addition to showing the hours, provide all the services of smart wristbands and many connect to the user's smartphone, making it possible to make payments, thanks to the embedded chips, see messages, answer calls, and control music through music apps compatible with these devices.

Many smart clothes are created also considering sustainability and compromise with the environment, using sustainable materials, reusing, and recycling the items. The examples go from sportswear to luxury apparels, baby clothes, college uniforms, and more. Examples of smart clothes include: (a) Start up BeClothed created intelligent underwear with a silver compound that eliminates bacteria responsible for bad smell, so the underwear can be used without getting dirty or smelling and does not need to be washed [3]; (b) MOxATech is Portuguese invented mask with an impermeable fabric that integrates waterproof and reusable covers, as well as a coating that inactivates the Covid-19 when it comes into contact with it [4]; (c) Italian Cliu Mask has a Bluetooth system, sensors, and algorithms, connected to an app in the smartphone of the user that gives information about the quality of the air, heart rate, and existence of some corona virus outbreak in the vicinity. With a disinfection system based on ultraviolet light, the mask allows to eliminate any virus it scans in a few minutes. It is a transparent mask because of people with hearing problems [5]; (d) Harvard and MIT also invented masks that, thanks to intelligent sensors, recognize the genetic code of the Covid-19 virus and light up when in contact with particles of the virus. This was a preventive solution for contacts with asymptomatic people. Similar masks are Leaf Mask, Flat Tube Energy, or TrioMed Active Mask ([2], p. 402); and (e) during the pandemic, Anouk Wipprecht created the "Proximity Dress" with many

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sensors that allow the dress to stretch creating a barrier if someone approaches, thus identifying the infringement of the mandatory safe distance due to Covid-19 .

There are devices with numerous functions, for example, clothing that tells if you have been in the sun too long, the distance you have traveled, speed, calories burned, or even devices that charge the phones or other electronics. Some include geolocation systems, fingerprints, or built-in facial recognition cameras that enable the control and location of their wearer ([2], p. 402).

Garments, footwear, wallets, and accessories with 3D and 4D technology may be protected by copyright and industrial property rights, and especially 4D items may raise problems related to the protection of personal data. In these cases, rules and regulations on personal data protection must be fulfilled with particular care.

2. Changes in fashion industry caused by 3D printing

Technology is evolving ever so rapidly that almost everything may be printed in 3D, in all sorts of materials and at low prices. If 3D and 4D fashion items are cheaper and more practical in daily life, this technology will continue to evolve. Currently, there are many designers involved in 3D and 4D in fashion industry. There are several platforms online where the user may buy 3D and 4D items, mainly in relation to clothes, wallets and purses, footwear, wearables, smart clothes, and accessories. There are several 3D platforms where it is possible to print the 3D CAD designs when the designer does not have a proper 3D printer, because it is too expensive. It is predictable that in the future many will have the economic capacity to buy a good 3D printer and print the CAD file designs from home. The fashion industry has to adapt, namely selling CAD files in a way that will allow users to print authentic item, not counterfeited, instead of buying them in physical stores on online stores. It is desirable that fashion companies will be associated with 3D or 4D printing platforms that may provide legal CAD files, allow customization by each user, and provide 3D or 4D printing services. This is a new paradigm in fashion industry.

2.1 Return to tailor-made

Thanks to 3D printing we may move from a fashion industry almost all based on *prêt-a-porter* to a tailor-made one. Three-dimensional (3D) printers are the sewing machines of the twenty-first century. The items are made according to the body and taste of the user. Prototypes rapidly become the end product. Three-dimensional (3D) fashion modeling is like architecture. One makes 3D scans of the measures and with the software makes the creation, being able to use unbelievable shapes. Cristiano Ronaldo, for example, has 3D-printed Nike soccer boots, customized according to medical advice regarding the weak points of his legs, knees, and feet. Patterns of injuries are detected, and the boots are designed to avoid them. The 3D soccer boots are lighter, totally customized, flexible, and completely adapted to the player's needs and taste ([1], p. 137; [6]). This happens with many important players of various sports.

In the autumn/winter 2018 collection, Demna Gvasalia, creative director of Balenciaga, used 3D scans of the bodies of the models and a CAD program to reach the desired tailoring. Tweeds and velvets were glued to light foam to create almost finished 3D-printed coats ([1], p. 137).

XYZ created the famous *InBloom dress* using an Ultimaker 3D printer, with PLD plastics. It is gorgeous, took 480 h of printing, has 1.7 kg of flexible plastic filaments, and seems a lace dress ([1], p. 137; [7]).

Italian trademark XYZBAG creates and sells 3D-customized bags [8].

The Spanish trademark ZAP&Buj-BUJ STUDIO creates clothes with flexible filaments on an elastic tulle fabric, which allows the adaptation of the piece to the movements of those who wear it [9].

Annie Foo creates high fashion 3D-printed shoes [10].

One of the more recent 3D dresses of Iris Van Herpen is the "Infinity Dress," that changes its appearance with movement [11].

Anouk Wipprecht above-mentioned "Proximity Dress," with many sensors that allow the dress to stretch creating a barrier if someone approaches, thus identifying the infringement of the mandatory safe distance due to Covid-19, is also 3D-printed [12].

2.2 Less logistic and transportation costs

Three-dimensional (3D) technology allows to manufacture less items and to cut on transportation costs. Manufactures and consumers approach, without or, at least, with less intermediaries, mainly transport companies. A fashion company may create the item in a CAD file and print it wherever it wants. If it is a Portuguese company of 3D-printed shoes, for example, with headquarters in Porto, they may be printed here, requiring a small team of experts for quality control. If, for example, this company were to open a branch in South Korea, the file of the shoes may be sent by the internet, namely by e-mail, and only 3D printers, a small team of control experts and distribution at the national scale, besides a place to store printed items, are needed. There is no need to search for the country with the cheapest production costs all over the world. Fashion companies may have reduced distribution chains and less storage needs.

The end user may participate in the process of manufacture, asking for the piece to be customized according to taste and needs. There is no need for large storage of the printed items. One can lower the number of printed pieces according to the requests of the consumers.

The whole manufacturing and distribution processes can be cheaper, sustainable, and democratic. We must not forget that many 3D printers, protected by patents, are falling into public domain, thus cheaper and legally able to be used by anyone, the same is happening with many invented materials.

2.3 Less undifferentiated workforce

As with all technological industries, the new production model needs less workers, especially undifferentiated ones. In the present, few items are done entirely in one single 3D-printed piece. It is still necessary to sew, to connect the 3D-printed parts. Like what happens with the sleeves and buttons of a coat, or the accessories that embellish the dress, for example. Anyway, less undifferentiated workers are needed, and they can work in the country where the items are 3D-printed, namely in the country where the company has its headquarters.

This may imply less work demand in underdeveloped countries, that do not respect human rights of the workers and have cheap labor force, and more demand in more developed countries. Items do not need to be transported to countries like Bangladesh, Pakistan, or Mexico, or even to India or China. In China, technology is abundant, but labor force is cheap, hence the interest in China of many fashion companies. Thus, 3D printing may contribute to the decrease of infringement of worker's rights. Less differentiated workers will still be needed to assemble 3D parts, give the finishing aspects of items, control quality, and work in smaller distribution circuits.

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Creating a fashion item will be each time more like creating a work of architecture, or a sculpture, with 2D and 3D phases, and will imply the use of software and large teams of experts. Designers, engineers, software and hardware experts, architects, economists, managers, marketers, big data, and trend experts, among others, can all be, in some way, involved in the fashion industry. We must not forget end users, consumers, that may become co-authors, if the company allows so (prosumers).

Resistance from undifferentiated or less differentiated workers and workers' unions is expected, and that is an important issue to be addressed.

2.4 A more environment friendly fashion industry

Three-dimensional (3D) fashion industry is more environment-friendly, causing much lesser pollution. An additive and non-subtractive technique means much lesser waist.

Plastics, which are everywhere, namely in the oceans, and cause great concern, are reused and recycled into 3D (or 4D) fashion items. These items can also be recycled and reused. Nowadays, 3D fashion also uses biodegradable materials. To mention some of the trademarks that already incorporated 3D fashion and use recycled plastics from the oceans, we may name Nike, Adidas, or New Balance sneakers and sportswear ([1], p. 139; [12]).

2.5 Approaching fashion from the virtual world

If fashion industry changes to be based in 3D and 4D technology, using CAD files, and printing less quantities of goods, many of them "intelligent," as happens with wearables and smart clothes, and if the items are increasingly sold online, namely allowing purchases through download of the files, sharing of the files, or 3D printing online platforms, the fashion industry will progressively dematerialize.

This approach to the virtual world was greatly sped up due to the Covid-19 pandemic, which led to the introduction of more and more augmented and virtual reality (AR and VR) in fashion, besides accelerating the development of wearables and smart clothes. Fashion trademarks are already entering the starting metaverses.

Augmented reality (AR) and virtual reality (VR) are already used in fashion. While virtual reality (VR) is totally immersive, augmented reality (AR) is partially immersive, meaning that the virtual experience overlaps the real word in AR. To have 3D virtual reality experiences, one must use helmets or glasses of VR. AR 3D experiences may be achieved through smartphones, projectors, or other hardware [13].

In fashion, AR may help trademarks to make fashion statements, stand out from the crowd, and connect with clients through new and exciting ways. AR is associated with entertainment, being very gratifying. The technology allows consumers to experience the item before buying it, which can reduce returns dramatically and allows access through social networks (namely Instagram and TikTok). If the experience is good, it has the potential to be shared and sharing can go viral, with new customers wanting to buy the product without the need for marketing or advertising. AR experiences can create fashion trends. There are several fashion companies that are using AR filters to attract new customers and engage existing ones. This was very important during the Covid-19 pandemic and has also to do with the importance of the use of social networks. Trying before buying increases profits by reducing returns, and as said above, this immersive experience can go viral. There is hardly a person that has never used social media filters. Without posting anything, one cannot avoid the temptation to find out how one will look like with blue hair, a certain shape of sunglasses,

dress, shoes, and so on. Among fashion trademarks that have these filters and other AR technologies, we find Gucci, Calvin Klein, Louis Vuitton, Zara, Burberrys, and H&M. AR technology increases costumers' confidence and helps to create data for analytics, because it helps to understand reactions of users toward new collections, thus allowing to predict and create trends. AR is good for the environment because it allows creation of digital clothes. Fashion influencers, bloggers, and everybody, can try them on and take pictures without having the physical item. Many AR techniques are being used in fashion. The AR Clothing Try-on is the dream of every passionate shopper, and one can access and experiment on any tablet or phone. For example, the luxury online shop FARFETCH used a particular feature under collaboration with the trademark Off White. The shop allowed costumers to try jackets from the collection using the photo messaging app. The 3D and stimulation technologies made clothes cling to the body on display and move by their actions. Virtual Tailors allows customers to know the exact size of the items based on their body measures. AR-powered virtual tailoring feature is used by Hugo Boss and Superdry. It helped to tailor the items to almost everybody measurements. Nike also combined tailoring and trying-on features, allowing the visitors of the app to measure their feet and find the correct size and virtually try on the item.

There are Colour-Changing apps that allow to change colors and patterns. For example, the American trademark American Apparel offered the costumers the possibility to scan the clothes on display in the shops and change their appearance using the application. AR Virtual Showrooms are a great idea for showing the collections worldwide in a much more sustainable way. Tommy Hilfiger made a digital display of the collection in Amsterdam. The audience could experience clothes by tapping an interactive touchscreen table and seeing every necessary detail on the screen.

Social media AR filters are very important because social media is a marketing star and every company that wants to succeed makes efforts in order to approach the audience in such platforms, for example, by creating custom social media filters. PE Nation, an Australian trademark, lets users try one of the pieces of their collection and imagine themselves being in snowy mountains. Virtual Make Over techniques are also available. Trademarks like Bobbi Brown, L'Oreal, and MAC launched try-on websites allowing customers to try lipstick, blush, or contour sticks before ordering them. AR or even VR is very important for new product launch because they allow for an immersive experience.

AR Mirrors are very interesting in clothing stores. In 2015, start-up Oak Labs presented interactive smart mirrors that allow costumers to see themselves in the reflection. Topshop and UNIQLO use similar technology. In the makeup market, Saks Fifth Avenue's beauty floor and Sephora launched "magic mirrors," allowing visitors to try makeup online. AR also succeeded in saving time when shopping. An In-Store-Navigation feature shows the shop visitors where to find the department they are looking for, or what items have special prices, which is very interesting in big department stores. AR allows better assortment in physical stores. Sometimes, the physical stores do not have all the items of the various trademarks they sell. To show them virtually is more sustainable.

In jewelery, which is expensive and delicate, using AR can be specially interesting because it can be hard to display the items in the physical placements, but costumers can try the items on using AR. Trillion Jewellery uses its app for virtual try-on effortless and fun.

AR expands advertising media options. Marketing is all about emotions, and AR can bring that emotional experience to advertising, and clients want to know more

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about the company and about it has to offer. Men's clothing Boohooman trademark transformed Black Friday into Hack Friday, creating the digital character and hacker Robin that appeared on all posters with QR codes placed during the campaign. Everybody could scan the code and see the character come to life talking about what the trademark offers. With AR, digital clothing can stand as stand-alone product. Virtual clothes and NFT's are so popular that in 2020 companies could rely on them to be the only selling item, which has also to do with the pandemic and the changes in the way people consume fashion. Studies show that in 2020 costumers started to use fewer products than those they bought, preferring digital items. The Fabricant is an all-digital company that creates virtual clothing since 2018. It became so popular that started to collaborate with trademarks like Puma and Tommy Hilfiger. DressX is also successful. The company uses AR to show that some clothes can exist only in their digital versions, thus contributing also to sustainability. In DressX app, one can find what digital clothes are best using smart AR filters. AR is strictly connected to games (gamification). Gamification in fashion is a big hit with AR technologies. Using AR, the company can create a fun and engaging gaming experience helping costumers to see what it has to offer, many times creating mini games. Victoria's Secret uses the game Pink line. By playing games and unlocking badges, costumers may know more about the company's products and gain exclusive offers [14].

There is an increasing interest of fashion trademarks to dress characters or avatars in games, like what happens with Balenciaga in Fortnite [15]. With games becoming more and more popular, fashion and AR have great potential to join and grow together. Louis Vuitton also created fashion items to the League of Legends, with great success [16]. In many cases, the digital items of the games can also be sold in the physical world and to inspire new collections (like the Balenciaga items). So, AR can come out of the virtual world of games and AR items can be also sold in physical way, namely 3D-printed. We are seeing an interesting and complex mixture between gaming and fashion.

The most recent win of AR happened when the Iridescence virtual dress was sold for $9500 during the Ethereal Summit in New York [14].

Zara also uses AR with great success to bring costumers to stores [15, 17]. AR technology in fashion business is very promising solution if adequately used.

Virtual reality is not so developed in fashion, and elsewhere, because specific hardware is needed, for example, VR helmets or VR glasses. Furthermore, totally immersive experience still has some unattractive reactions, as some individuals experience dizziness or other mild symptoms after experiences in virtual games. Interesting aspects of VR include the possibility of adding gloves with sensors, simulating touch, and creating more interactivity with the virtual items.

During the pandemic, VR started to have an important role in fashion because there could be no presence showrooms and fashion weeks. Virtual runway fashion shows were created to allow the users to virtually attend them, which led to democratization of those fashion shows by trademarks that sent VR helmets or VR glasses of those virtual runways to potential clients. Another important aspect of VR has to do with the buying experience. Companies like Tommy Hilfiger offer their clients the possibility to visit their virtual shop (that is like some of the most emblematic shops of Paris, New York, or London) because in cooperation with technology giants they got the know-how to create the virtual store. The experience allows to hear the music existing in the physical stores and to access parts of the runway, obtaining a 360 view of each design chosen by the client ([2], p. 404).

AR and VR in fashion will extend to metaverses, that is, virtual places where second lives that are starting to appear and attract people that do not want just the

real life they live in, and whose avatars must be dressed according to the status they have. Many fashion companies are already investing in metaverse, often described as a network of virtual places linked into a virtual universe, and considered a future version of the Internet. In the metaverse, customizable avatars and dynamic group experiences enable a new era of social interaction. Concerts, parties, happy hours, and religious ceremonies are increasingly taking place virtually, with individuals participating regardless of their geographic location, especially in the aftermath of Covid-19. Metaverse members will engage with and purchase digital and real-world apparel, sporting goods, and other items through virtual shopping malls [18, 19].

3. Fashion and videogames

A videogame is an electronic game that can be seen in a screen. It is a type of audio-visual work and protected as such by copyright. It is a very profitable fast global growing market. The pandemic led to a huge growth of the videogames market. Fashion companies saw the opportunity and joined the videogames world.

Balenciaga was pioneer. Trying to avoid the Covid-19 to affect its fashion market even more, adapted to this new business concept presenting its collection fall/winter 2021 in the videogame "Afterworld. The age of tomorrow."

It is a futurist game, located in 2031, trying to create a future where clothes can transform themselves in order to be reused and last in time. The game is a virtual runway show, where existing and designs of future collections are shown, but the avatar engages in surpassing proofs and in different adventures, like what is common in videogames ([2], pp. 376–377).

Louis Vuitton cooperated with American e-sports *Riot Games* in the creation of the "League of Legends." The cooperation is based in many projects, like the creation of a trunk for the "Summoner's Cup," or the collection *LVxOL,* with a garment style based on the game, which is very appealing to the gamers and to the followers of *Louis Vuitton*. The trademark reaches a public which, otherwise, would not be possible to reach ([2], p. 377).

Celebration 200 years from the birth of the founder of the fashion house, *Louis Vuitton* created a videogame called "Louis the game," that was a continuation of the videogame "Endless Runner" and appeared in 2019 for the Fall and Winter Collection 2019. "Louis the game" is an app of interactive games that pays tribute to the founder of the company through the eyes of *Vivienne*, the mascot of the workshop, that enters a digital world to celebrate the birthday of the founder of the house *Louis Vuitton* ([2], p. 377).

This game uses the *Blockchain* technology, including 30 *Non-Fungible Tokens*, 10 of them created by the American digital artist, graphic designer, and performer Beeper. Nevertheless, the *Non-Fungible Tokens* of this game cannot be sold, and they were created only for the purpose of collection ([2], p. 378).

Moschino decided do dress "the Sims" in 2019. The fashion company included a capsule collection inspired in the famous game. The models entered the virtual world allowing for the characters of the game to be dressed with *Moschino* clothes ([2], p. 378).

In the gaming domain, we must also mention the "Animal Crossing" saga of videogames of Nintendo. Thanks to its popularity many fashion houses decided to use the characters of the games to present their collections in a very creative way. *Valentino* house included its Spring Summer collection 2021 in this videogame allowing the user to immerse in a true photoshoot in which the 3D characters of Nintendo are the protagonists and use items of the collection. The images may then be carried to

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the Instagram page (@animalcrossingfashionarchive) where, with a certain code, the user may buy the desired item through a web page ([2], pp. 387–388).

4. Fashion, Blockchain, and Non-Fungible Tokens (NFTs)

The *blockchain* technology is being used in fashion in many ways [20–22]:

a. to guarantee the authenticity of the items. One of the main characteristics of the blockchain is immutability; thus, it is possible to make a chain of transactions through the application of blockchain solutions to those fashion items that are object of sale, in order to guarantee their origin, who designed it, the trademark owner, among other things. Therefore, it is simpler to identify and locate counterfeit products or products that present alterations with respect to the product initially marketed by a fashion company. In March 2019, the *LVMH Moët Hennessy-Louis Vuitton (LVMH Group*) released the launch of the project "Aura," developed by Quorum, Microsoft, and Consensys. The project is based in a blockchain solution that allows to verify the authenticity of the products of the fashion company, uniquely identifying its origin and authorship in real time. This procedure favors transparency and confidence of the clients. *Vestiaire Collective* uses the advantages of *blockchain* technology in an *online* platform for the sale of high-end fashion and accessories. The platform has a group of fashion experts that certifies the authenticity of the products. After this process of verification and validation, the article is incorporated with a technological footprint through blockchain technology, accompanying its entire useful life, as a sign of authenticity and quality, against possible counterfeits ([2], p. 388).

b. to guarantee the transparency of the production chain. In the last year, it has become increasingly important for companies to respect ethics, culture, and social aspects. Clients want to be informed about the origin of the products, location of factories, compromises with the environment, and respect of human rights. *Blockchain* technology can help to reassure the transparency, the security, and the legality of the production chain. The technology implies the incorporation in each garment of a QR code (*Quick Response Code*) that contains all information about the entire manufacture process ([2], p. 389).

c. With smart contracts. *Blockchain* technology allows the creation of *smart contracts,* or intelligent contracts, whose main characteristics are its automatic fulfillment and execution. The *smart contracts* run autonomously, via command *if-this-then-that,* when the factual assumption contemplated by the contract is fulfilled. This type of contract is very useful when there is an objective component, such as the activation of the payment because of the receipt of a specific remittance or the payment for the contracting of an insurance or financial product. Intermediaries are eliminated and, therefore, the costs ancillary to the contract are considerably reduced. With the ever-increasing evolution of *Blockchain* technology, *smart contracts* can be utilized and integrated into the domain of *Intellectual Property Rights* to digitize and secure transactions of such intangible assets while ensuring trust, transparency, and safety of both the enforcer and the consumer ([2], p. 390).

The *Non-Fungible Tokens (NFTs)* are digital assets whose value is granted by the user, or whoever is willing to pay at a certain time, since, through this type of tokens, a kind of collectible and unique objects are created. These features are very attractive in fashion and art, where what is exclusive and unique is highly valued, and *NTFs* grant authenticity. Each *NFT* has a single valuation, being part of a certain *blockchain*. Thus, what one acquires buying an *NFT* is, mainly, a license or an asset to sell in the future.

What the sale of NFT and the purchase of haute couture garments through this way entails is that the buyer acquires the use of them, that is, acquires an implicit and nonexclusive license for its use. Copyright is not transferred to the buyer, unless expressly agreed by the seller, as the intellectual property right remains in the possession of the author who created the garments.

This new business model led to the emergence of digitally native fashion trademarks in the market, that is, trademarks that lack physical showcases or recognized names in the conventional fashion industry and sell their products through *NFTs*.

Some examples of these trademarks are: Overpriced, with its sale of a virtual sweatshirt such as TFN by 22,000 euros; RTFKT and its sale of digital sneakers, paying homage to the culture of the game; DressX, a fashion store in which customers buy a garment and send a photo of themselves, receiving in return a digital photo of them wearing the garment they have bought, and its essence lies in the fact that users buy clothes to upload photos on the networks; and Auroboros, as last example, is the first fashion house that merges science and technology with physical haute couture [2].

5. Three-dimensional (3D) fashion and intellectual property

Three-dimensional (3D) fashion must respect copyright, related rights, and industrial property rights, namely patents, utility models, design patents, trademarks, trade dress, logotypes, denominations of origin, geographical indications, rewards, trade secrets, and rules against unfair competition.

Three-dimensional (3D) and 4D files must respect intellectual property rights and whoever 3D prints must have the authorization of the copyright or of the industrial property right (trademark, design, patent, or other right) owner. Because in EU copyright laws register is not mandatory, as a rule, it may be difficult for the 3D printer to know whether the CAD file comes from a legal origin. This is essential to ensure the absence of counterfeit. Industrial property rights, as a rule, must be registered, so it may be easier to know if the item comes from a legal source, at least in the EU [23–26].

The problem is private use. One must deal with the difficulty to grant the enforcement of intellectual property rights when the CAD files and its online sharing and 3D printing are done for strictly private uses. In copyright, the situation is not covered by exceptions or limitations and does not fulfill the three-step test. Regarding industrial property rights, laws must be adapted in order to forbid not only 3D printing with economic or commercial goal but also private uses. A company's profit is affected when the consumer decides to print counterfeited items instead of buying the legal ones. If necessary, industrial property laws must be changed, considering the deliberate 3D printing of counterfeited trademarks illegal, logotypes, or designs, among others, even for private uses [27].

An important way of preventing piracy could be to protect the CAD files that contain a work or other protected industrial property exclusive rights. Protection should also involve the CAD files. The CAD file that has a trademark, for example, will be protected as if it was the trademark itself.

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Regarding the price of the 3D printers, that is, the hardware, an amount ought to be for copyrights, related rights, and industrial property rights owners, as it happens with uses for private copying in relation to reproduction right for private use in the EU in copyright and related rights.

Technological measures to protect the CAD files and digital rights management systems would also be important to enforce intellectual property where 3D technology is used, including the possibility of the use of technology of destruction of illegal CAD files.

Blockchain technology grants intellectual property rights owners against non-authorized exploitation by third parties regardless the link in the production chain in which the articles are located. *Smart contracts* can be utilized and integrated into the domain of *Intellectual Property Rights* to digitize and secure transactions of such intangible assets while ensuring trust, transparency, and safety of both the enforcer and the consumer.

Enforcement is essential in the 3D fashion market. Fashion is already very affected by piracy, and hacking is a big issue to address when we are approaching the dematerialized fashion world.

Fashion companies can be affected in their reputation when the pirated items lack quality, and the consumers will associate them to the companies affected by the illegal copies. Additionally, if the CAD files and the 3D-printed items are not approved by a quality department and cause damages to the consumer, the producer will be liable, but we must find an effective way to find who is the actual producer.

6. Personal data protection

Wearables and smart clothes raise questions related to personal data protection [28, 29].

Wearables and smart clothing products come in many shapes and sizes, but all of them have sensors that allow a series of functions. For example, some shirts monitor the heart rate, activity, and breathing, and sleepwear garments can track sleep levels and sync data to the smartphone. Football fans will also have noticed that footballers are increasingly wearing under-shirt garments that resemble a sports bra. It is a form of smart clothing containing a GPS tracking device that records data about the players' movements. This also happens in other sports and activities. Data such as heart rate, daily strides, and calories burned, as well as location and route data are recorded. This is a lot of sensitive information. Manufacturers are bringing more and more new technologies for recording a wide range of body and movement values onto the market. This is also reflected in the sales trend in the wearable sector. The best known and most successful devices in this field are smart watches and bracelets that function as fitness trackers. For the functionality of the wearables and the apps, the operators usually record data as time, location (GPS), heart rate, blood pressure, sleeping behavior, calorie consumption, pedometer, and much more. In addition to smart watches, many fitness trackers also become smart and provide information about incoming calls, upcoming appointments, messages, and notifications from social networks. With all this information, a personal profile of a person can be created. Now rings, earrings, and pendants start to perform the same functions of smart watches and bracelets.

Besides the personal data included in wearables and smart clothes, the way in which the data are sent is very important. These are recorded in the wearables (or

smart clothes). The raw data generated by the sensors are then usually transmitted to the own smartphone (or other wearables or smart clothes) via Bluetooth. There the user can then view them in evaluated form. Adding to that, most manufacturers collect and store all captured data in a cloud. For all these reasons, it is fundamental to protect these personal and sensible data.

Despite concerns about data protection, wearables and smart clothes also offer great potential. The technology opened and will open many new areas of application. Especially in the medical field, there are many development opportunities. Sensors can detect diseases at an early stage and support medical care. Each time, more companies are developing clothing equipped with sensors and smart fibers that offer completely new possibilities. Smart garments can detect movements and touches in addition to the recording of classical health data. This offers ideal possibilities for recording and optimizing motion sequences in certain sports, as aforementioned. This means that data protection issues will arise each time more.

The wearable and smart clothes industry is still starting to develop. It has great potential, but with data protection issues will arise. It is fundamental to know how data are obtained, how they are stored and transmitted, and what they are used for. When one buys wearables or smart clothes, it is very important to know the general terms and conditions and data protection declarations. Attention should always be paid to the possibilities for deleting the collected user data to avoid possible future discrimination. Furthermore, there is always the right to request the stored data from the manufacturers.

Legislation is also fundamental. In the EU, there is, among other acts, the important Regulation (EU) 2016/679 of the European Parliament and of the Council. This General Data Protection Regulation *(GDPR)* is a European Union regulation on data protection and privacy in the EU and the European Economic Area (EEA). It is an important component of EU privacy law and of human rights law, in particular Article 8°, n°1 of the Charter of Fundamental Rights of the European Union [30, 31].

7. Conclusions

Three-dimensional (3D) printing became the sewing machine of the twenty-first century, causing great changes in the fashion industry, namely the appearance of more sustainable, and customized apparel and accessories, simpler logistics and less transaction costs, increased creativity, and cooperation of specialists from many different areas. The final idea of prosumer and its meaning is before us. If we add 4D printing, that is, "intelligent" materials, 3D printing enters our day lives, with wearables and smart clothes. If we add the recent developments achieved by augmented reality and virtual reality and metaverses, the fashion world becomes even more virtual and sustainable, and buying is each time more connected to a gaming experience. All this raises numerous questions regarding copyright and industrial property protection and possible infringement in those areas.

Three-dimensional (3D) and 4D files must respect intellectual property rights and whoever 3D prints must have the authorization of the copyright or of the industrial property right (trademark, design, patent, or other right) owner. Because in EU copyright laws register is not mandatory, as a rule, it may be difficult for the 3D printer to know whether the CAD file comes from a legal origin. This is essential to ensure the absence of counterfeit. Industrial property rights, as a rule, must be registered, so it may be easier to know if the item comes from a legal source, at least in the EU.

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It is difficult not to infringe intellectual property rights when the CAD files, its online sharing, and the 3D or 4D printing are done for private uses. In copyright, the situation is not covered by exceptions or limitations and does not fulfill the three-step test. Regarding industrial property rights, laws must be adapted to also forbid 3D and 4D for private uses and not only with economic or commercial goals.

An important way of preventing piracy could be to protect the CAD files that contain a work or other protected industrial property exclusive rights. Protection should also involve the CAD files. The CAD file that has a trademark, for example, will be protected as if it was the trademark itself.

Regarding the price of the 3D printers, that is, the hardware, an amount ought to be for copyrights, related rights, and industrial property rights owners, as it happens with uses for private copying in relation to reproduction right for private use in the EU in copyright and related rights.

Technological measures to protect the CAD files and digital rights management systems would also be important to enforce intellectual property where 3D and 4D technology is used, including the possibility of the use of technology of destruction of illegal CAD files.

Enforcement is essential in the 3D fashion market. Fashion is already very affected by piracy, and hacking is a big issue to address when we are approaching the dematerialized fashion world.

Fashion companies can be affected in their reputation when the pirated items lack quality, and the consumers will associate them to the companies affected by the illegal copies. Additionally, if the CAD files and the 3D-printed items are not approved by a quality department and cause damages to the consumer, the producer will be liable, but we must find an effective way to find who is the actual producer.

Wearables and smart clothes raise questions regarding personal data protection. The issues to be raised are multiple because we are faced with sensors or sensor terminals. Data security of the device itself in transmission and storage must be addressed. It is fundamental to know how data are obtained, how they are stored and transmitted, and what they are used for. When one buys wearables or smart clothes, it is very important to know the general terms and conditions and data protection declarations. Deleting the collected user data is fundamental to avoid possible future discrimination. Furthermore, there must always be the enforceable right to request the stored data from the manufacturers.

Legislation is fundamental. In the EU there is, among other acts, the important Regulation (EU) 2016/679 of the European Parliament and of the Council. This General Data Protection Regulation *(GDPR)* is a European Union regulation on data protection and privacy in the EU and the European Economic Area (EEA). It is an important component of EU privacy law and human rights law, in particular Article 8°, n°1 of the Charter of Fundamental Rights of the European Union.

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fashion. Gucci releases first Virtual 25 sneaker that can only be worn in AR (dezeen.com) [Accessed: 20 October 2022]. Before that in July 2020, to promote their new sneaker collection, Gucci partnered with Snapchat to launch their first global augmented reality shoe try-on campaign on the platform. They created AR try-on lenses to let Snapchat users see how Gucci sneakers look on their feet. The collaboration was a huge success. Augmented Reality Can Be Real Gucci | by Han Nguyen | Marketing in the Age of Digital | Medium [Accessed: 20 October 2022]

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