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3D Printing in Fashion

[1]Matthew N. O. Sadiku, [2]Olaniyi D. Olaleye and [3]Janet O. Sadiku,
[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]Barbara Jordan-Mickey Leland School of Public Affairs, Texas Southern University, Houston, TX, USA
[3]Juliana King University, Houston, TX, USA

Abstract: 3D printing, also known as additive manufacturing, is a process that crafts three-dimensional objects by layering materials on top of each other. Unlike traditional manufacturing techniques involving carving or shaping solid blocks, 3D printing constructs objects layer by layer. 3D printing is transforming the fashion industry, revolutionizing the way clothes are designed, produced, and customized. Designers and clothing producers can use the technology to create fantastic 3D printed fashion with shapes and geometries never made before. In this paper, we will explore how 3D printing technology is reshaping the fashion industry.

Keywords: *3D Printing (3DP), Additive Manufacturing (AM), 3D Printing in Fashion, 3D Printing in Clothing*

I. INTRODUCTION

Traditionally, a printer is used at home or in the office to print out text and images on paper. This conventional printer prints in a flat two-dimensional (2D) space using the dimensions length and width. A three-dimensional (3D) printer uses length and width but also adds depth to the print. A 3D printer has more manufacturing capacity than a traditional manufacturing machine. It is regarded as a disruptive technology that will change manufacturing. It has been used for decades in the automotive and aerospace industries. The 3D printer is also used by hobbyists, small businesses, creatives, manufacturers, architects, and most importantly contractors to instantly create a variety of products.

Fashion brings together several industries, whether it is clothing, cosmetics, or luxury. All sorts of products are being created to embellish and affirm a style, a look, a way of being. Before the industrial age, fashion was made mainly by tailors. Clothing mass production started in the mid-19th century, when several factories began to make clothes that did not require tailoring.

Now imagine a world where you can effortlessly design and create your own clothes from the comfort of your own home. The fashion industry is known for its constant need for innovation and creativity, and 3D printing provides a new platform for designers to push the boundaries of what is possible. From shoes and accessories to 3D printed dresses, the fashion industry is embracing the full potential of 3D printing and to develop interesting objects. 3D printing is a technology that has the potential to revolutionize the fashion industry since it will bring a lot of flexibility to the industry [1].

II. WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then, it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceutics, consumer products, education, entertainment, medicine, space missions, the military, chemical industry, maritime industry, printing industry, and jewelry industry [2]

A 3D printer works by "printing" objects. Instead of using ink, it uses more substantive materials–plastics, metal, rubber, and the like. It scans an object–or takes an existing scan of an object–and slices it into layers, which can then convert into a physical object. Layer by layer, the 3D printer can replicate images created in CAD programs. In other words, 3D printing instructs a computer to apply layer upon layer of a specific material (such as plastic or metal) until the final product is built. This is distinct from conventional manufacturing methods, which often rely on removal (by cutting, drilling, chopping, grinding, forging, etc.) instead of addition. Models can be multi-colored to highlight important features, such as tumors, cavities, and vascular tracks. 3DP technology can build a 3D object in almost any shape imaginable as defined in a computer-aided design (CAD) file. It is additive technology as distinct from traditional manufacturing techniques, which are subtractive processes in which material is removed by cutting or drilling [3].

3D printing has started breaking through into the mainstream in recent years, with some models becoming affordable enough for home use. Many industries and professions around the world now use 3D printing. It plays a key role in making companies more competitive. The gap between industry and graduating students can be bridged by including the same cutting-edge tools, such as 3D printing, professionals use every day into the curriculum. There are 3D printed homes, prosthetics, surgical devices, drones, hearing aids, and electric engine components. As shown in Figure 1, 3D printing involves three steps [4]. A typical 3D printer creating a dress is shown in Figure 2 [5].

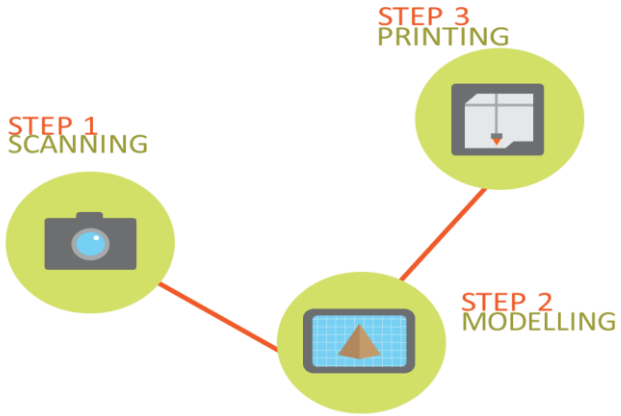

Figure 1: 3D printing involves three steps [4].

Figure 2: A typical 3D printer creating a dress [5].

III. 3D PRINTING IN FASHION

3D printing has taken the fashion industry by storm, revolutionizing the way we design, produce, and consume clothing. Fashion designers have already unveiled shoes and clothing made via 3D printing, in which plastic material is deposited layer upon layer to create a three-dimensional structure. As technology advances, new 3D printing techniques are being developed, pushing the boundaries of what is possible in the world of fashion.

There are several different types of 3D printing techniques. Some of the most commonly used techniques in the fashion industry include [6]:

- *Fused Deposition Modeling* (FDM): This style involves extruding a continuous stream of molten material through a nozzle to build up the layers of the object. It is often used in the production of wearable accessories.
- *Stereolithography* (SLA): This technique uses a liquid resin that is solidified layer by layer using a laser or UV light. This is a popular tool for creating high-detail prototypes, small-scale production runs, and jewelry accessories.
- *Selective Laser Sintering* (SLS): This approach uses a laser to selectively fuse powdered material together to form the object. This is often used for creating functional parts and components.

IV. APPLICATIONS

Ever since the dawn of 3D printing, designers and inventors have been trying to come up with groundbreaking ways to utilize its capabilities. The 3D printing process is a good way to give life to objects with complex designs and to make them wearable as traditional garments. While 3D printing is still relatively new in the fashion industry, there are already a number of applications that have embraced this technology. Common applications of 3D printing in fashion include the following [7,8]:

1. *3D Printed Cloths:* 3D printing on clothes represents a captivating chapter in the ongoing narrative of fashion evolution. Instead of 3D printing full items of clothing, 3D printers in fashion are used to supplement parts of a whole design, like embellishments, accessories, and buttons. The 3D printing has been used to create extremely complex and impressive pieces. Examples of 3D printed cloths are shown in Figure 3 [9]. The most important application is still in the customization of private clothing for film and television props.

Figure 3: Examples of 3D printed cloths [9].

2. *3D Printing Costume:* It is now possible to use additive manufacturing to create costumes for the film industry. The main goal here is to create a lightweight costume, with an ambitious design but that should not hinder the dancer's performance.
3. *3D Printing Shoes:* The 3D printing technology is revolutionizing the footwear industry as well as the sport industry. In the past, the technology was mainly used in the footwear industry to 3D print midsoles. Today, 3D printing can directly print the sole or the entire shoe, as shown in Figure 4 [10]. Some important brands such as Adidas are making the most of additive manufacturing to develop impressive projects. Adidas created a 3D printed midsole for one of its sneakers, made with recycled plastic found in the ocean. The company Feetz is taking a new approach to footwear by creating an entirely 3D printed and customizable shoe.

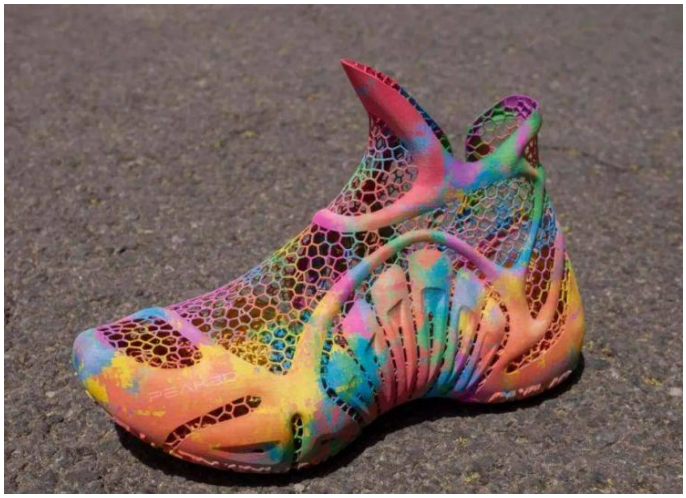

Figure 4: 3D print of shoe [10].

4. *3D Printed Jewelry:* This is now becoming more and more common. 3D printing is a perfect method to launch a jewelry business. One of the key advantages of 3D printed jewelry is the freedom it offers in design. With traditional jewelry manufacturing techniques, certain complex and intricate patterns may be challenging or impossible to achieve. The 3D printing technologies are suitable for the creation of your jewelry parts or jewelry molds. Resin and plastic 3D printing can also be used for jewelry projects. Figure 5 shows as 3D-printed watch [11].

5. *3D Printed Bags:* Accessories like bags can also be produced using 3D technology. These bags are customizable, offering the possibility to play with geometries and try new things.
6. *3D Men's Wear:* Imagine a jacket that is so comfortable, that it would not feel like a jacket. Being 3D printed, there was no need to have seams. The jacket can be custom-made for each individual's body shape and size. A typical men's 3D-printed clothing is shown in Figure 6 [12].
7. *3D Printed Accessories:* 3D printers are available to consumers to create simple fashion accessories at home like bracelets, cellphone cases, bags, and even fake nails. Some companies use the SLS technology to create accessories. Such an accessory is shown in Figure 7 [13].

Figure 5: A 3D-printed watch [11].

Figure 6: A typical men's 3D-printed clothing [12].

Figure 7: 3D-printed accessory [13].
Figures p. 11**(clothing), 17(future of clothing), 102(accessories), 191(bag)

V. BENEFITS

The impact of 3D printed textiles on the fashion industry is multifaceted. 3D printing technology allows designers to create intricate pieces that were once deemed unattainable. A major advantage of 3D printed textiles is the positive environmental impact. This technology is really giving a lot of freedom to the designers in terms of geometry. Other benefits of 3D printing in fashion include the following [5,6]:

1. *Speed:* One of the key advantages of 3D printing in fashion is its ability to significantly speed up the design and production process. Traditional manufacturing methods can be slow and time-consuming, involving multiple prototypes and iterations. With 3D printing, designers can quickly turn their ideas into physical objects, reducing the time from concept to creation.
2. *Customization:* Another major advantage of 3D printing in fashion is the ability to create customized and personalized items. Each person has a unique body shape and size, but traditional mass production often fails to cater to individual needs. 3D printing allows designers to create garments and accessories that are tailored to each individual's measurements, ensuring a perfect fit.
3. *Sustainability:* The fashion industry has been known for its negative impact on the environment, with fast fashion and excessive waste being major concerns. Air pollution is a major concern in textile producing giants like China. 3D printing benefits sustainable fashion efforts due to the reuse and recycling of materials to create new designs. It offers a more sustainable alternative by significantly reducing material waste. Unlike traditional manufacturing methods, 3D printing only uses the amount of material necessary to create the desired object.
4. *Precision:* 3D printing allows for the precise control of material use, reducing waste and offering a sustainable alternative to traditional methods. The technology ensures that only the necessary amount of material is used. Precision in material use translates to reduced production costs, also making 3D printed garments a more financially viable option.
5. *Waste Reduction:* 3D printing creates products layer by layer, reducing material waste. Unlike traditional manufacturing, 3D printing uses only the material necessary for each item.
6. *Localized Production:* 3D printers can be placed strategically in regions with high demand, reducing the need for long-distance shipping and minimizing the carbon footprint associated with transportation.
7. *On-Demand Production:* Instead of producing clothing in large quantities and risking overstock, fast fashion brands can employ on-demand production. This ensures that products are made only when they are ordered, reducing excess inventory and waste.
8. *Availability:* With 3D printing, it is far less hassle to create clothes on demand. Designer clothing is expensive because it is made to fit your body, and it takes time to produce it. A 3D printed design is cheaper and quickly made available and hence can allow for faster availability of clothes.

VI. CHALLENGES

While the benefits of 3D printing in fashion are many, there are several challenges that need to be overcome for widespread adoption. The fashion industry must adapt to fully embrace the technology. 3D printing projects in the fashion world are often monochrome, and are not as colorful. Other challenges of 3D printing in fashion include the following [6]:

1. *Material Limitations*: One of the main challenges in 3D printing fashion is the limited range of materials available. 3D-printing materials are far more rigid than the fabrics used in clothing. The majority of 3D printed fashion is still made using plastics. This limits the variety of textures, colors, and finishes that can be achieved with 3D printed garments and accessories. Designers and researchers are exploring different materials, such as algae-based filaments and recycled plastics, to create more eco-friendly 3D printed fashion.
2. *High Cost:* Another challenge of 3D printing in fashion is the high cost of the technology and the limited accessibility for designers and consumers. 3D printers can be quite expensive.
3. *Expertise:* The expertise required to operate and maintain 3D printers can be a barrier for many designers. Fashion designers and architects who plan to use 3D printers to make jewelry, accessories, and clothing will need to invest some time and money into learning modeling software.
4. *No Mass Production:* The fashion industry is built on mass production and consumption, which poses a hurdle. Shifting the industry towards on-demand, customizable, and recyclable products will take time. Due to limitations in materials, cost and production efficiency, there is no business opportunity for mass production.
5. *Copyright:* Similar to music and movie piracy, design file piracy can also affect the fashion industry. Illegal sharing of designs for fashion items can hurt the original creator of the design.

CONCLUSION

Fashion visionaries are using 3D printing to create mind-bending textiles that are nearly impossible to wear. They dreamed of 3D-printing textiles that were bulletproof, fireproof, pressure-resistant, or able to trap heat or cold. As the technology continues to evolve, we will see its impact on the fashion industry, leading to a more sustainable, innovative, and personalized future for fashion. The heightened interest in 3D-printed clothing serves as a compelling reason for fashion retailers to stay abreast of the latest advancements in 3D printing. 3D printing is offering great advantages for the fashion industry, from 3D printed clothes to 3D printed footwear and accessories, the possibilities are endless. Some experts foresee a day when we could print out customized garments right in the store or at home, on demand. The future of 3D printing holds immense potential for revolutionizing the way we design, create, and wear fashion.

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ABOUT THE AUTHORS

Matthew N.O. Sadiku is a professor emeritus in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interest include computational electromagnetics, computer networks, and marriage counseling. He is a life fellow of IEEE.

Olaniyi D. Olaleye is a Registered Civil and Structural Engineering Professional. He is also a Project Management Professional (PMP®). He obtained Ph.D. degree from Texas Southern University, Houston, Texas. He is an author of several professional papers and books. His areas of research interest include civil and structural engineering, water resources and environmental engineering, climate change adaptation, renewable energy, and infrastructural sustainability.

Janet O. Sadiku holds bachelor degree in Nursing Science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and doctoral degree from Juliana King University, Houston, TX in December 2023. She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, and Canada. She is a co-author of some papers and books.