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Mini Review

A Mini-Review on the Applications of 3D Printing Technologies in Textile Design and Manufacturing

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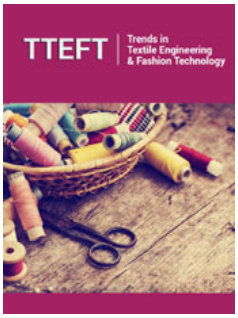

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Abstract

3D printing can revolutionize textile engineering and fashion design by introducing new possibilities for customization, rapid prototyping, and the creation of complex designs in a similar manner that it revolutionised other forms of manufacturing. Today Various 3D printing technologies exist ranging in terms of material, printing quality and printing method. In textile engineering, several challenges exist regarding the utilisation of 3D printing technology since fabrics by design require a different weaving process than the one supported out of the box by existing 3D printing technologies. In this review paper, we outline the possibilities that 3D printing technology has brought to the textile manufacturing and textile design industry.

Keywords: 3D printing; Textile manufacturing; Textile design

Abbreviations: 3D: Three Dimensional; FDM: Fused Deposition Modeling; SLA: Stereolithography; SLS: Selective Laser Sintering; DLP: Digital Light Processing; DMLS: Direct Metal Laser Sintering; EBM: Electron Beam Melting; MJP: MultiJet Printing

Introduction

Today there are several types of 3D printing technologies available. Fused Deposition Modeling (FDM) can be considered the most common and affordable 3D printing technology working by melting a thermoplastic filament and extruding it layer by layer to create the object [1]. Stereolithography (SLA) uses a liquid resin that is cured by a UV laser to form solid layers and has the capacity of producing high-resolution and detailed models [2]. Selective Laser Sintering (SLS) is a process where a laser selectively fuses powdered materials, such as plastics or metals, to create the object layer by layer [3]. Digital Light Processing (DLP) is a 3D printing method that is similar to SLA but uses a light source, such as a projector, to cure liquid resin. Considering that entire layers are cured at once DLP is considered faster in printing speeds [4]. Various metal 3D printing technologies exist, such as Direct Metal Laser Sintering (DMLS) and Electron Beam Melting (EBM). These methods use lasers or electron beams to selectively melt metal powders to create metal objects [5]. Finally, MultiJet Printing (MJP) utilizes an inkjet-like printhead to selectively deposit liquid photopolymer onto a build platform in combination with a UV light that is used to solidify the material [6].

In this paper, we make a review on the advancements regarding the usage of 3D printing technology for textile design and manufacturing. 3D printing technology has evolved in many ways in the past decade and the main technologies employed have been made available in the form of open-source designs. These radically changed the landscape mainly through the evolution of the makers' movement and the adaptation of such designs to achieve various goals including for example the high-resolution capturing of planar surfaces and their reconstruction in the form of image mosaics [7] and 2.5 D digitisations [8].

At the same time, rather than adapting 3D printing technologies, another track regards its application in new fields. For example, in textile design, 3D printing allows for

the creation of prototypes, customized accessories, and textile tools. It enables designers to quickly iterate and test their ideas, fabricate personalized components, and develop unique fabric-like structures. 3D printing aids in the optimization of textile processes, such as weaving and knitting, by producing specialized tools and accessories. In fashion design, 3D printing technologies offer the ability to produce intricate prototypes, highly detailed jewellery and accessories, and custom components for garments and footwear. Designers can experiment with complex geometries, textures, and material combinations to create visually appealing and unique designs. 3D printing also supports the integration of wearable technology into textiles, enhancing the functionality and aesthetics of wearable devices.

Discussion

Fused deposition modelling

FDM 3D printers are often used in textile engineering to create prototypes, functional parts, and accessories. They can produce flexible and wearable objects by using flexible filaments or combining rigid and flexible materials. FDM is also used to create customized textile tools, such as fabricating moulds for textile casting or designing unique textile structures. Several approaches have already studied the aesthetic qualities of 3D printing for textile design [9-11]. At the same time, several 3D-printed products have been used in the context of fashion designs (e.g. [12]).

To achieve the above-mentioned innovations, research efforts in this domain focused on various aspects of FDM printing for textile manufacturing. For example, evaluating the adhesion strength between FDM-printed PLA parts and surface-treated cellulosic-woven fabrics is important to understand whether it is possible to create enduring composite textiles by printing on top of woven fabrics [13-16] following previous research efforts on printing on top of textiles [17-19] or mixing textile and 3D printed layers [20]. At the same time, creating flexible textiles while not capable to weave with a 3D printer has also received attention by proposing 3D structures that cat replicate the effects of a woven fabric [21]. Other approaches focused on creating flexible textile-like 3D-printed materials without requiring elastic filaments that are challenging to print [22,23].

Stereolithography (SLA) and Digital Light Processing (DLP)

SLA and DLP printers are commonly used in fashion design to produce intricate and highly detailed prototypes, jewellery, and accessories. These technologies enable designers to experiment with complex geometries and intricate patterns, allowing for the creation of unique and visually appealing designs.

Research efforts in this domain focussed on the evaluation of resin adhesion to various textile fabrics and the effect of resin chemical solvents on the printed fabrics during the cleaning and curing process. Cleaning is the process of removing non-cured resin from the printed fabric, while curing is the process of hardening the printed resin through exposure to UV light [24].

Selective Laser Sintering (SLS)

SLS printers are valuable in textile engineering and fashion design for producing functional and durable parts using a wide range of materials, including nylon and other polymer powders. SLS technology can create intricate fabric-like structures, interlocking mechanisms, and even 3D-printed shoes. It offers design freedom and the ability to create complex and lightweight textile components.

Research with SLS technology has produced extremely interesting results in terms of printing textile structures since proof of concept has been implemented that with the usage of SLS technology and nylon powder managed to create actual flexible weft knitted structures. The results show the potential to print flexible textile-based structures that exhibit the properties of traditional knitted textile structures. Furthermore, the mechanical properties of the material used have been also studied [25,26].

Metal 3D printing

Metal 3D printing technologies, such as Direct Metal Laser Sintering (DMLS) and Electron Beam Melting (EBM), are technologies that are based on melting metal powder to create an object via laser or electron beams. Since this produce solid printed objects, they have applications in creating high-end jewellery, accessories, and textile components [27-30]. These processes allow designers to work with precious metals like gold, silver, and titanium, enabling the production of intricate and customized metal designs.

MultiJet printing

MJP technology has shown potential in creating detailed textile patterns, intricate textures, and prototypes in the field of textile engineering and fashion design. It offers high resolution and the ability to incorporate multiple materials in a single print, allowing for the development of visually appealing and functional textile objects.

Conclusion

Considering the outbreak of 3D printing technology in the past decade there is a significant impact already in the domain of textiles and fashion design that yet has not covered the potential of the various printing technologies. It is foreseen based on what existing literature has displayed, that each technology will play an important role in the future.

FDM will probably continue to play a significant role in textile design and manufacturing. In the future, we expect that more advanced filament materials with enhance the flexibility, durability, and even electrical conductivity of the printed fabrics. This will enable the creation of complex, flexible textile structures with integrated sensors and electronic components. FDM's accessibility due to open designs has the potential to make it a tool for rapid prototyping and customization in both small-scale and mass production.

Regarding SLA and DLP technologies since currently are mostly used in the design of luxury accessories are more probable

of finding increased application in high-end fashion design. As these technologies become more affordable and offer larger build volumes, designers will have the possibility to explore the creation of larger-scale intricate garments and accessories. A current limitation is their ability to print with a single material thus if multiple materials are supported in the future both rigid and flexible elements within a single design will be possible.

SLS has the potential to revolutionize textile manufacturing by enabling the creation of complex, functional textile structures from a variety of materials, including polymers and even composites. Thus, it is expected, in the future, that as materials improve and become more diverse, SLS could enable the production of customized, high-performance fabrics with specific mechanical properties tailored to different applications.

Metal 3D Printing is more likely to be employed in luxury fashion and high-end accessories, since the reduction of cost will make it feasible to 3D print intricate metal jewellery and components, even with precious metals.

MJP technology's high-resolution capabilities are relatively new for the fashion world. It is expected that probably these will find applications in textile designs that require intricate textures, patterns, and surface finishes by enabling the design and printing of textile moulds used for casting, intricate textile accessories, and even highly detailed fabrics for high-end fashion pieces.

As a general remark regarding the future of 3D printing technologies, a trend is starting towards sustainable and environmentally friendly materials and since the fashion industry faces increasing pressure to reduce waste and environmental impact, 3D printing could offer solutions through smart production methods and less material wastes. At the same time, another trend in smart textiles and wearable technologies will likely expand and their 3D printing is expected to have a fundamental role. As a final remark, it should be considered that since the above discussion provides speculations regarding future trends the actual trajectory might differ as the industry continues to evolve.

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Conflict of Interest

No conflicts of interest.

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