LIFESTYLE PRODUCT VIA 3D PRINTING: WEARABLE FASHION

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ABSTRACT: Lifestyle products reflect individuals' way of life and resonate with personal identity. Some of the examples of lifestyle products are home décor, sports equipment, music instruments and fashion. With up-and-coming companies offering 3D modeling and printing services, consumers can easily access 3D printers to incorporate creativity and personalize touches into individual lifestyles. The use of AM has also helped to create a new platform for customization, direct customer review as well as rapid prototyping of the design concept. In this paper, the feasibility of using 3D printing for lifestyle products, particularly wearable fashion products, will be discussed in terms of the aspects of design processes as well as fabrication processes for the wearable fashion application.

INTRODUCTION

Lifestyle products reflect individuals' way of life and resonate with personal identity. Some examples of lifestyle products include home décor, sports equipment, music instruments and fashion. With up-and-coming companies offering 3D modeling and printing services, consumers can easily access 3D printers to incorporate creativity and personalize touches into individual lifestyles.

Additive manufacturing (AM) or 3D printing has been widely adopted in the lifestyle products, for example in the manufacturing of jewelry and accessories as well as customized toys and figurines. It has also garnered much attention in the apparel industry and an increasing number of well-known fashion designers have experimented apparel design using AM. 3D printed haute couture showcased on the fashion runway has influenced both the consumers and manufacturers in the fashion world in terms of the design, functionality, customization as well as fabrication techniques. Fashion designers such as Iris van Herpen and Francis Bitonti, are among the first fashion designers to collaborate with 3D printing companies to introduce 3D printed haute couture. Dutch fashion designer, Iris van Herpen, has received numerous awards for her collection 'Voltage' featuring 3D printed garments fabricated using the Selective Laser Sintering (SLS) technology. The design has shown the great possibility of using AM to fabricate AM wearable fashion.

In this paper, the feasibility of using AM for lifestyle products, particularly wearable fashion products, will be discussed in terms of the aspects of design processes as well as fabrication processes for the wearable fashion application, learning from the examples of the apparels from the 2013 Singapore International 3D Printing Competition organized by Nanyang Technological University.

PROCEDURE

Comparing to the general AM process flow (Chua, Leong, & Lim, 2010), AM process flow for wearable fashion requires additional procedures prior to the general AM process flow, as depicted

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in Figure 1, are required. Before creating CAD model for the garment design, it is necessary to obtain the body size, either through the use of 3D body scanning technology or using manual measurement. After this step, individualized body contour can be obtained in the CAD software and the garment design can be mapped onto the body curves to obtain a good-fitting outfit design.

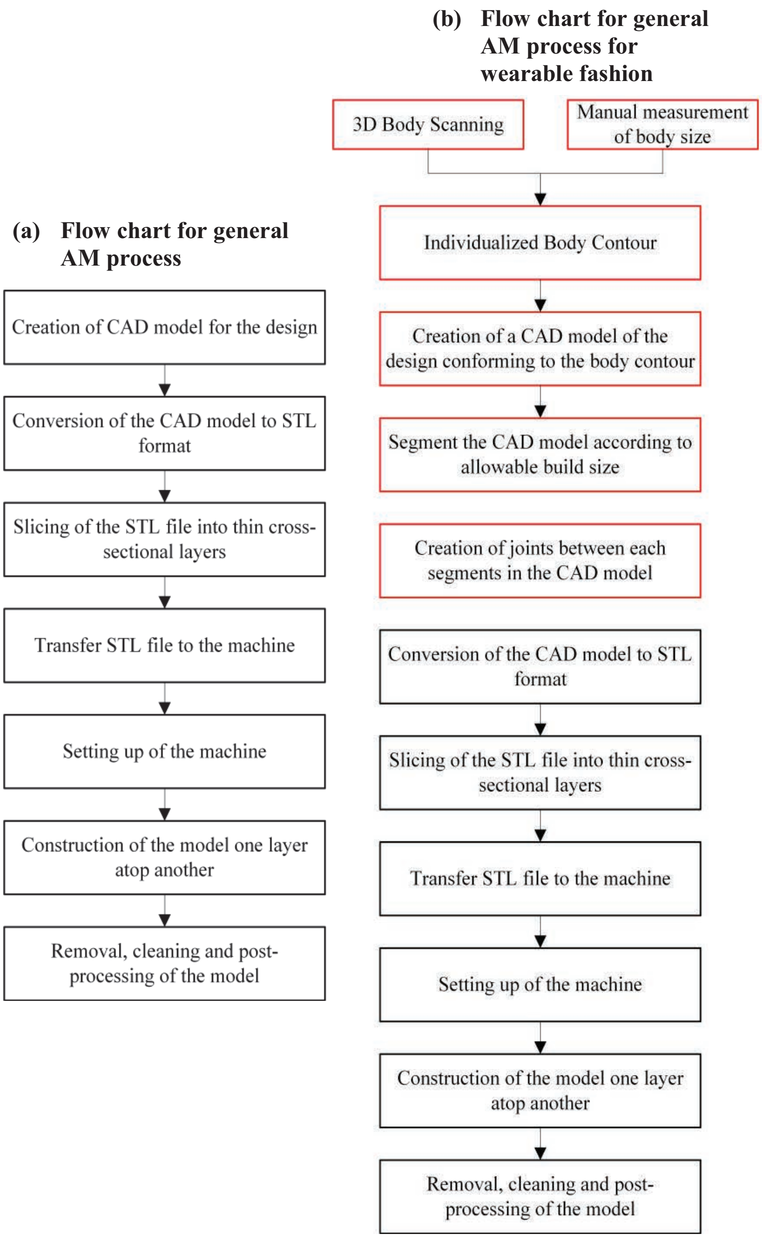

Figure 1: (a) process flow for general AM; (b) process flow for AM fabricated wearable fashion

After generating the CAD design, the 3D model has to be segmented into smaller printable pieces according to the build volume of the AM machines. In addition, joints also have to be designed into the CAD model to facilitate joining of the small sections using adhesives or other methods. Finally, after the print job is completed and the small sections are assembled, the AM fabricated wearable fashion would undergo post-processing such as dyeing and lacquering to improve the aesthetic of the printed products.

DESIGN PROCESS

The process flow of AM has shown that additional procedures are critical to fabricate wearable fashion during the design stage. Creation of CAD model of the garment design can be done using most of the CAD software. Selection of suitable CAD system as well as segmentation and inclusion of joining mechanism in the CAD design during the design process are also some of the important parameters to consider for CAD modelling of the design.

Data capturing and design modeling

Using the 3D body scanning technology, AM allows mass customization of the garments to produce body-fitting garments that are perfectly tailored for the wearer (D'Apuzzo, 2007). In addition to the ability to customize, this new technology also provides a platform for direct customer review through the virtual 3D CAD model of the 3D printed garments before commencing fabrication. Customers and designers could digitally design and customize the apparels without the need of prototyping to test fit, color and sizing.

After obtaining the 3D scanned body contour using non-contact 3D scanning technology, the garment design has to be mapped and conformed to the body contour. Alternatively, CAD design can be worked on the body curves directly using most of the CAD software available in the market. Nearly every 3D CAD system is able to produce the output files accepted by the AM machines, such as STL (STereoLithography) file format. The STL file format is a boundary representation to approximate 3 dimensional surface geometry using triangular facets (Gibson, Rosen, & Stucker, 2010).

Solidworks, AutoCAD, PTC Creo and Rhinoceros (Rhino 3D) are some examples of professional CAD software that are commonly used in the field of engineering, architecture, product design and industrial design, Solidworks and Rhino 3D are often employed for product designs like wearable fashion. Solidworks is generally used by engineers to create engineering models while Rhino 3D is widely used in the product design and architecture industry. Solidworks is a hybrid solid and surface modeler while Rhino 3D uses NURBS in surface modelling. This has explained why Rhino 3D is easier to work with complex curved surfaces as compared to Solidworks. Rhino 3D is a more suitable CAD software to do 3D wearable fashion design where curved surfaces are essential.

Segmentation and digital patterning

Due to the limitation in the build volume of the AM machines, the complete apparel design needs to be segmented into smaller pieces to fit into the allowable build size of the selected AM machine. Segmentation of the design file could be done easily in the CAD software, there are, however, many other important considerations to take note of, for example, material consumption and surface finish in a particular orientation, build time and the aesthetic of the overall design. The 'Hydro-shift' top in Figure 2(a) provides a good example in cutting the design into multiple small sections. The top was being cut symmetrically along the center and the cut lines are elegantly hidden within the design. In addition, the cut line also enables each section to be printed flat down on the build tray to save time and cost. On the contrary, PolyJet fabricated 'Water Bridge' dress design was made up of only 4 huge sections that each could fit into the build tray while the cut lines were simply made at the convenient locations. This has resulted in wastage in support material and difficulty in joining these sections together firmly.

Bonding mechanisms

The small sections have to be assembled together to form the final fashion product using special joining technique. It is common to use adhesive to bond the small sections together. However, extra surface area is required for the application of adhesives to ensure firm adhesion between two sections. In order to facilitate the adhesive bonding without affecting the overall aesthetic of the design, extra tabs that have similar pattern with the corresponding section were created at the interior side, as illustrated in Figure 3.

Bonding mechanism without the use of adhesive could also be created to assemble the small sections together. When there are thin struts in the design like the 'Rippling Embodiments' design, mechanical joints like helical spring and cufflink-like objects are useful to join two or more sections together, as shown in Figure 4. Helical springs coiled around the thin struts are able to provide firm yet flexible joints. Instead of using adhesive, the cufflink-like objects could serve as detachable joints that may be easily removed or installed.

FABRICATION PROCESS

Digital fabric and systems

Fused Deposition Modelling (FDM), Fused Filament Fabrication (FFF) and PolyJet are commonly employed to fabricate the 3D printed wearable fashion. Materials available for the three AM systems are vastly different but most of them work exclusively on the specific AM machine.

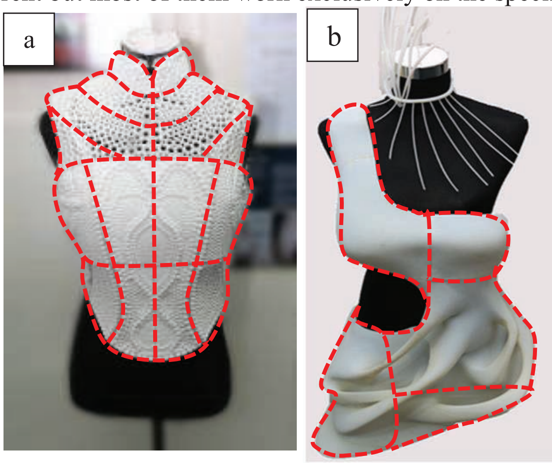

Figure 2: (a) 'Hydro-shift' top design made up of 26 sections; (b) 'Water Bridge' dress design made up of only 4 sections with cut lines as shown in dotted lines.

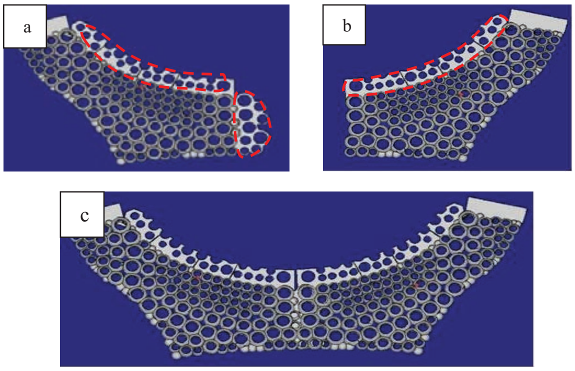

Figure 3: (a) (b) Sections from 'Hydro-shift' top with the additional tabs inserted in the CAD model; (c) the two sections combined after adhesive bonding

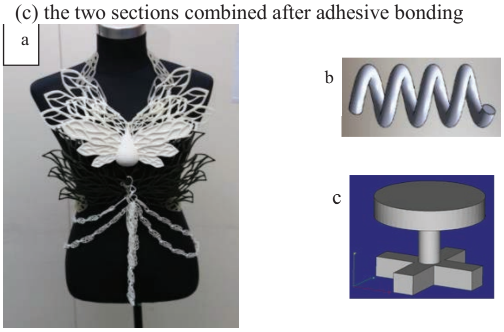

Figure 4: (a) 'Rippling Embodiments' design made use of small joining elements such as (b) helical spring and (c) cufflink

Table 1: Shortlisted AM systems, materials available for the system as well as the features of AM systems

AM System	Materials Available	Features
Fused Deposition Modelling (FDM) – Stratasys Dimension Elite	- ABS Plus	- Limited range of materials - Only rigid ABS available - Good resolution
Fused Filament Fabrication (FFF) - Ultimaker	- ABS - PLA - Flexible PLA	- Wider range of material as compared to FDM - Flexible PLA filaments available - Reasonable resolution
PolyJet – Stratasys Eden350V	- Rigid material (Vero) - Rubber-like material (Tango) - Polypropylene-like material	- Wide range of materials with different hardness - Excellent resolution

The features of each AM system and the materials available exclusively to the machine are shown in Table 1. It is noted that the selection of the right material for the 3D printed apparels is highly dependent on the AM system chosen. Nevertheless, in order to select the right materials, the materials should fulfil most of the important attributes: flexibility, durability, tear resistance, surface finish and weight. Flexibility, which can be derived from the hardness and flexural behavior of the material, is an important aspect in apparel as the garment needs to be flexible to conform to the body curves while not restricting movement. The 3D printed wearable fashion needs to be able to be used repeatedly hence the material must also be durable and be able to resist tears. Surface finish of the printed products also needs to be good to appeal to the customers while the apparel is expected to as lightweight as possible to be on par with the traditional apparels.

Flexible PLA filaments available in the FFF system as well as Tango materials from PolyJet are suitable choices of material that satisfy most of the requirements as discussed. It should be noted that there are other AM systems that are already being employed to fabricate wearable fashion, for example, Selective Laser Sintering (SLS) using Nylon 12. All the current materials from FDM, FFF, PolyJet and SLS, however, still could not satisfy all the requirement substantially. Strong demand for truly wearable 3D printed apparels will fuel the development of new materials, as a result new materials or even new AM systems that cater to this application are expected to be seen in a few years' time.

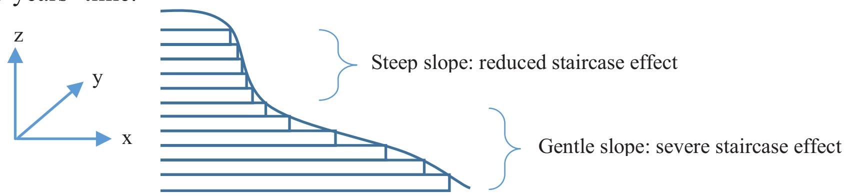

Figure 5: Staircase effect as a result of surface inclination

Build orientation consideration

Build orientation of the parts could be defined before printing. It is essential to orientate the build part correctly in order to produce good surface finish as well as to minimize support material usage and build time for the case using FDM and PolyJet. Taking FDM as example, the surface finish is largely affected by the layer thickness and the inclination of the surface. Staircase effect is more visible in gentle slope as compared to steeper slope, as illustrated in Figure 5. On the other hand, build time as well as the support material required are dependent on the overall geometry and the orientation of the build parts. Building in the z-direction would generally increase the total build time due to the non-productive time to lower the platform after each layer and time taken during wiping of nozzle and shifting of nozzles (Thrimurthulu, Pandey, & Venkata Reddy, 2004).

CONCLUSION

General process flow of fabricating wearable fashion using AM was introduced. Several significant design considerations were also explained using examples from the 2013 Singapore International 3D Printing Competition organized by Nanyang Technological University. In addition, selection of AM machines and materials as well as the importance of choosing the right building orientation were highlighted as part of the fabrication process of the wearable fashion. In conclusion, although current AM materials are limited to produce a truly wearable apparel for everyone, this new technology possesses a huge potential in the apparel manufacturing industry in the near future to shape the new generation of customizable high tech apparels that are designed as lifestyle product.

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