Innovative application of 3D printing technology in Fashion design

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Abstract. The vigorous development of 3D printing technology has brought more innovative design inspiration to Fashion design. Designers have launched 3D printed clothing that subverts the traditional aesthetic. Taking the 3D printing parametric Fashion design method, process technology and material analysis as the premise of the study, the article discusses the innovative application of 3D printing technology in Fashion design from three aspects, including 3D printed clothing natural aesthetic design, bionic design and fusion with big data. In the innovative research of 3D printed clothing, the design aesthetics of Iris van Herpen is viewed as an example to analyse the aesthetic form of clothing. Furthermore, the article explores the aesthetic meaning and styling characteristics of 3D printed clothing and explains aesthetic characteristics from the perspective of design science. The feasibility of 3D printed Fashion design was discussed from the perspective of shape, color and texture bionics. The fusion of 3D printing technology and big data has gradually become an inevitable trend, and fresh forms of Fashion are booming.

1 Introduction
Modern apparel fabrics and production processes can no longer carry designers' more innovative design concepts. Only can the combination with the most popular 3D printing technology make Fashion design more vigorous. In the field of 3D printed clothing, Iris van Herpen, a Dutch designer, enjoys a great reputation. The 3D printed clothing designed by her is extremely innovative and leading the new trend of Fashion design. In the top-level Fashion show, 3D clothing designed by her has changed the public traditional perception of clothing design, such as the series of crystal in water, bionic spiral, white skeleton, transparent crystal[1]. Israeli designer NoaRaviv, by 3D printing technology, uses materials of nylon and resin to produce garments with complex geometric structures[2], which enriches people's knowledge of garment production materials. At present, many domestic and foreign Fashion designers are actively exploring the innovative application of 3D printing in the field of Fashion. The article is based on 3D printing technology and new materials of craftsmanship to explore the natural aesthetic design, bionic design of 3D printed clothing, and innovative applications in fusion with big data.

2 Concept of 3D clothing parametric design and process material analysis

2.1 Parametric design
Parameterization is a method to solve objective design problems with the help of computer computing power. It is widely and flexibly used in Fashion design[1]. The typical parametric design tool is
Grasshopper (abbreviated as GH) which is a 3D parametric building on the Rhion platform[3]. The designer gives the design instructions, then GH generates design parameters and calculates the design parameters to generate the final model. For example, if the shape of a curve needs to adjust, it only needs to change the parameters of the curve (such as space area and space diameter). Rhion software is a 3D software (as is shown in Fig. 1) that can easily build a three-dimension structure, so that it is widely used by designers, illustrators and engineers. 3D printing technology is a carrier based on parametric design of clothing, which can help designers print patterns with high accuracy. Besides, new materials suitable for 3D printing are emerging, and its performance is comprehensive. For example, a TPU92A-new material developed by Materialize have super physical properties and excellent resilience, which can quickly return to its original state after being squeezed. At Paris Fashion Week, the models wore clothes printed with this material and walked onto the T stage.

2.2 3D printing technology materials and processes
In the field of 3D printing, material is an important factor that determines the art of 3D Fashion, and it is also the foundation for the development of 3D printing technology innovation so that material occupies a pivotal position. At present, 3D printing materials mainly include new plastics, resin materials, metals and composite materials. The details are as follows.

Table 1 Analysis of advantages and disadvantages of materials

| Material name       | advantage                                                                 | disadvantage                                                                 |
|---------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------|
| ABS plastic         | 1. Stable material characteristics and strong wear resistance             | 1. The platform needs to be heated to 80℃~120℃                               |
|                     | 2. Strong color fastness                                                  | 2. It is not easy to mass-produce large-scale production                      |
| ALS Nylon powder    | 1. Strong heat and wear resistance                                        | 1. Less color selectivity                                                    |
| material             | 2. High tensile strength                                                  | 2. The production temperature is harsh                                        |
| Photosensitive resin | 1. High strength and fast curing speed                                    | 1. Poor heat and wear resistance                                              |
|                     | 2. Smooth appearance after production, suitable for customized clothing   |                                                                               |
|                     | 3. High material recycling rate                                            |                                                                               |
| Rubber materials    | 1. Favourable toughness and high softness                                 | 1. Low reutilization rate and poor environmental protection                   |
|                     | 2. Suitable flexibility and strong comfort                                |                                                                               |

3D printing technology is divided into a variety of different processes according to different material forming methods and processing equipment, three common classic 3D printing processes are FDM, SLS and SLA, their characteristics are shown in the following table.

Table 2 Analysis of various process methods

| Process method | Main materials | Heating temperature | Advantages                                      | Disadvantages                        |
|----------------|----------------|---------------------|------------------------------------------------|--------------------------------------|
| FDM            | ABS plastic    | 230~250℃           | 1. cheap price                                | 1. The surface is rough and needs a frame |
|                | PLA plastic    | 195~210℃           | 2. High utilization                           | Poor flexibility, single texture     |
|                | Plastic powder | 180~195℃           | 1. Strong support                             |                                     |
|                |                |                     | 2. Not easy to deform                          | rough surface                       |
3 3D printing achieves the natural aesthetic design of Fashion

Traditional clothing textile fabrics fit the human skin, the fabric materials and manufacturing processes limited the aesthetic design innovation of Fashion. However, 3D printing technology uses new materials such as nylon powder and photosensitive resin to expand the design of Fashion from traditional two-dimensional space design to three-dimension, which can carry more bold and innovative design concepts of designers. 3D printing technology can innovatively realize the natural aesthetic design of Fashion, which makes clothing with more dynamic beauty, cascading beauty and structural beauty originating from the nature to achieve the integration of Fashion and art.

3.1 Dynamic aesthetic design

The flowing of water is free and running, showing a dynamic beauty with a water-like appearance that is not constrained by the carrier. Incorporating the dynamic beauty of the water element in the Fashion design can not only give the clothing a natural three-dimension sense, but also convey the designer's unique design concept and the worship of the vitality of nature. 3D printing technology can help designers achieve this great innovation. Fortunately, Dutch Fashion designer Iris van Herpen has made innovative attempts in this regard. In the fall and winter 2011 haute couture show, the splash works used 3D printing technology to freeze the dynamic beauty of splashes in the clothing as shown in Fig. 2 below. It presents the natural dynamic beauty of turbulent, crystal clear and pure water droplets colliding with the water surface giving the viewer a quite emotional and free visual impact.

![Fig. 2 Freezing splashes of clothing works](image)

The dynamic beauty of 3D printing technology in clothing design is more than that. Perhaps designers can make the following innovative attempts. (1) The design of the skirt hem can use 3D printing technology to freeze the curve formed by the trajectory of the water drop, so that the skirt hem can reflect the streamlined dynamic beauty from top to bottom; (2) The ripples of the water spreads from the center to the surroundings. Taking the position of the human head as the center, the 3D clothing fluctuates from top to bottom like a water grain spreading to the periphery, which can perfectly display the sparkling dynamic beauty. 3) 3D printing technology manufacture various dynamic beauty clothing accessories like water sparkling. Therefore, 3D printing technology can help designers achieve various dynamic beauty designs, and many innovative applications are yet to be explored.

3.2 Layered aesthetic design

With the help of computer three-dimension modeling software, clothing designers can design three-dimension stacked three-dimension drawings with smooth curves and more artistic innovations. The use of 3D printing technology can produce hard-supporting clothing that traditional fabrics cannot achieve. The clothing has a more three-dimension cascading beauty, which can better show personality and charm.

The Fashion designer innovatively tried the mermaid clothing series. They use a computer to draw a three-dimension blueprint of the mermaid art clothing, the next step is to print out the mermaid art
clothing skeleton adopting 3D printing technology, and then designer perform color rendering later to make the clothing more bionic. 3D printing technology can make the clothing show the layered and silky beauty of the fish scales in the mermaid costume. Moreover, it can restore the "mermaid" sci-fi beauty to the greatest extent like Fig. 3-2).

Designers can use the layered superposition of lines to form a visual three-dimension sense and use it in Fashion design. By polishing the line curve design stage, it can form a tightly interwoven and tough and stylish technology product. 3D printing technology contributes to showing the lines-overlap beauty such as Fig. 3-3) and 4). The performance is most vivid, the stacking of lines is ever-changing, and 3D printing technology can be used to incubate all kinds of clothing-style works, such as the first fully hinged 3D printed dress as shown in Fig. 3-1). This dress overlaps woven black lines and forms rhombic patterns between them. Not only does it highlight the perfect figure of the wearer, but also it can give people a layered beauty combining strength and technology. The most amazing thing is that the three independent parts of the shoulder are stacked in a staggered manner, which perfectly demonstrates that the 3D printing technology brings the aesthetics of clothing art stacking.

3.3 Structural aesthetic design
The structural design of clothing is a necessary link to transform design inspiration into works of art. By using the advantages of computer software in three-dimension structural design, structural modelling and reconstruction among points, lines and surfaces, designers can create clothing shapes that conform to the human body structure. Clothing modelling with obvious structural aesthetic design cannot be separated without the support of 3D printing technology.

The inspiration of structural aesthetics in Fashion design can be obtained from the structural characteristics of objects in nature, and then through the innovative reconstruction of the designer in the later period, a clothing work with a sense of structural art may be presented to the public. Designers can try from the following aspects: 1) It is the shell thread structure from the ocean just like Fig. 4-1). The shell shows a regular thread structure that spreads from the center to the edge through the light, which has a high appreciation. The surface of the shell is too smooth, and the surface curve shrinks to the center dot, showing a perfect three-dimension pattern aesthetic. Therefore, the shell thread structure is
integrated into the clothing design, the works can perfectly display the texture changes and the three-
dimension structure using 3D printing technology, and the overall work will be amazingly beautiful.
2) The integration of mathematical geometry into Fashion design will also be a bold innovation, such as
hexagonal structure shown in Fig. 4-2) and pentagonal structure shown in Fig. 4-3). The designer only
needs to extract the mathematical geometry as shown in Fig. 5 painted by the author, and arrange the
developed geometric patterns in a continuous three-dimension space, and then use the computer to evolve
parametrically, we can design clothing works with tight space arrangement, strong three-dimension
sense and rich structure. Fashion design only needs to boldly incorporate an innovative sense of structure,
In the future, 3D printing can achieve all designer inspiration and make clothing more structurally
beautiful.

1) Circular structure stack design  2) Thread structure design drawing
Fig. 5 Structural aesthetic design drawings by writer

4 3D printing realizes clothing bionic design
The introduction of bio-bionic design in Fashion design has a history. With the application of 3D
printing technology, it has helped the rapid development of bionics in Fashion design. The so-called
clothing bionic design refers to that the clothing designer takes biology as the research object, extracts
biomorphic elements, colour elements, three-dimension elements and other information, and integrates
its creativity into the clothing design, which makes the clothing more ornamental and unique. 3D
printing technology has gradually matured to make clothing bionic design easier to implement. The
following will be elaborated from three aspects: shape bionic, colour bionic and texture bionic.

4.1 Morphological design
The form of creatures is rich and colourful, and it is the source of Fashion designers' inspiration for
creation. Fashion design can be based on figurative bionics and abstract bionics to carry out the
configuration design of biomorphic elements. The difference between the two is that figurative bionic
clothing strives to reproduce and depict the biological image in nature most realistically. However,
Abstract bionic clothing is based on biological form, integrates the designer's creative thinking, and
incorporates processing methods such as mixing, segmentation, and gradation showing a refined design
concept and strong regular beauty

1) Wing shape bionic design  2) Bionic design of pangolin  3) Snake morphological bionics
Fig. 6 Bionic shape design in 3D clothing printing

Designers can perform figurative bionics from the outward appearance of animals such as leopards,
pangolins, cats and other animals. Leopards show movement and strength. By using 3D printing
technology, designers can combine the streamline beauty and curvy beauty of leopard animals to create
sports series clothing. Figurative bionics on the outer carapace of pangolins, the layered beauty of the carapace can be perfectly presented using 3D printing technology. Designers can also create three-dimension drawings of interweaving lines and regular arrangement from the stretching and abstraction of plants such as meridians of leaves. Besides, they used 3D printing technology to create a winged clothing series. Designers should boldly try to use innovative forms of bionics to enrich the content of Fashion design and expand the boundaries of clothing design. Fig. 6 presents several representative morphological bionic 3D printed clothing.

4.2 Color bionic design
According to the designer's expected goal, 3D printing color bionics selects the bionic objects and extracts the color attributes, color areas, and color shapes of the bionic objects, and then designer performs color rendering and brainstorming on the first draft of the design by using computer-aided design. Finally, the 3D printing technology is used to produce the design drawings. The skin color of creatures in nature is colorful, the surface color of creatures is very ornamental after a long period of evolution, and the color matching between different colors is very artistic. Fashion designers should boldly try 3D printing color bionic design to redefine the color design of clothing. For example, jellyfish, a kind of marine life, gradually changes from light blue to transparent from top to bottom showing a fairy-like color change. The use of jellyfish color bionics for wedding dresses, group swings, and other 3-print apparel designs can better reflect the colorfulness and richness of clothing as shown in Fig. 7-1) and 2). Another example is the bionic design of 3D printing on the color of parrot feathers, which can design gorgeous Fashion clothes in Fig. 7-3). Nature is like a treasure chest of colors, there are still many wonderful colors that require designers to use 3D printing technology to explore color bionic design.

4.3 Bionic texture design
Texture bionics meet the basic aesthetic needs of 3D printed clothing, it uses materials with clothing-like texture properties to create natural visual and tactile effects through the surface shape, texture and structure of the bionic materials to achieve the sense of conscious dislocation on the material. Texture bionics are currently used in 3D printed apparel design, including bionic fibers, bionic fabrics, and bionic composite materials. For example, the SLS series of the London Fashion Week in autumn and winter 2014 was printed by using the EOS FORMIGA P100 system, and the laser sintering technology was used to sinter the nylon cloth into a regular diamond-shaped top. At present, more designers and materials scientists are required to make innovative attempts in bionic composite materials.

5 Integration of 3D printing and big data leads Fashion design
How does 3D printed clothing meets the modern consumer's aesthetic needs and how does it lead the Fashion trend of clothing is a topic worth thinking about. The emergence of big data gives 3D printed clothing design an opportunity to lead Fashion trend. Clothing designers can build a large database of 3D printed clothing elements, then 3D printed clothing design can integrate different clothing elements according to inspiration, which makes 3D clothing design easier using this database. By analyzing consumers' preferences for 3D printed clothing and the dressing style of mass, designers can design 3D printed clothing that meets consumer preferences in a targeted manner based on big data analysis, which
helpe 3D printed clothing lead the market demand. 3D printed apparel and big data are like two legs, only when the two are deeply integrated can 3D printed apparel can develop in a sustainable and innovative way, so that 3D printed apparel can lead Fashion design.

5.1 3D printed clothing accessories
Another innovative application of 3D printing technology is to continue to explore the development of 3D printing in the field of clothing accessories in conjunction with big data analysis. 3D printed clothing accessories can make breakthroughs in 3D printed bags, 3D printed shoes, and 3D printed hoodies. 1) The design of the 3D printing bag should be more functional, stylish and environmentally friendly. For example, a 3D printed bag designed can carry pets so that women can more easily shoelace pets for shopping, and it also can be used as a temporary stool so that women can rest when they are tired. 2) 3D printed shoe designed should be more creative and stereoscopic. For example, the sense of plant rattan veins is integrated into the design of shoes to produce retro and highly breathable Fashion shoes. 3) The design of 3D printed hoodies should use lightweight materials, which are more breathable. The surface of the hood is sprayed with ultraviolet absorbing materials during the 3D printing stage, the bionic design gives the hoodie better functions and Fashion elements. Fig. 8 shows representative 3D printed clothing accessories.

Fig. 8 3D printed Fashion accessories

5.2 Personalized advanced customization
At present, individualized high-level customization is a field of competition for 3D printed clothing. Different forms of 3D printed high-level customized clothing appear at Fashion Week, which constantly impacts people's perception of clothing Fashion. Individualized advanced customization needs to be further explored, using big data to analyze individualized differences is the breakthrough point of individualized advanced customization. Big data can establish basic data indicators of the human body, obtain changes in human body phase indicators, predict the short-term and medium-term shape changes of the human body, and then using big data analysis can provide designers with very informative opinions, which design of individual advanced custom clothing can perfectly match customers' short-term needs.

6 Conclusion
3D printing apparel design is an important trend for future apparel design. How does a Fashion designer can design an innovative 3D printed apparel will affect the development direction and social recognition of 3D printed apparel. This article presents pertinent innovative application solutions from three aspects of 3D printed clothing natural aesthetic design, bionic design and big data fusion, and gives some innovative design concepts, which has great reference value for Fashion designers. 3D printing apparel is in the early period of development, and for the maturity of 3D printing technology, promotion of 3D printing materials and 3D printing apparel, they need to continue to be explored, but future innovative application solutions in the future will certainly emerge in an endless stream.

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