Bouncing with 3D Printed Soft Cells

Young-A Lee and Yu Li, Auburn University, USA

Keywords: 3D printing, textile innovation, 3D prototyping, wearables

Contextual review and concept statement. In the current digital transformation era with the emphasis on consumers' personalization through design, 3D printing, an innovative manufacturing method, has attracted much attention from various industries including the fashion industry. Previous studies have explored the potential use of 3D printing and its materials in wearables' design and the differences between 3D printed textiles and traditional fabrics (e.g., Kim et al., 2019; Pattinson et al., 2019; Uysal & Stubbs, 2019; Valtas & Sun, 2016). The majority of 3D printed garments were created through selective laser sintering (SLS) with Nylon or fused deposition modeling (FDM) with other rigid filaments, for example, Nervous System's (2014) Kinematics dress and Kim et al.'s (2019) 3D printed dress. However, most 3D printed wearables were composed of rigid hinge-joint interfaces or interlocked chainmail (e.g., Chen, 2020; Lee & Kwon, 2017; Sun & Parsons, 2014), leading to relatively low flexibility compared to apparel made of traditional fabrics. Although designers started to adopt flexible 3D printing materials such as thermoplastic polyurethane (TPU) in wearables' design (e.g., Cui & Sun, 2018; Sun, 2018; Sun, 2017), it has been only used in a small section of the wearables (e.g., bra, gloves). Creative design scholarship on 3D printing with flexible materials for wearables' design is still limited. Thus, we challenged to develop 3D printed dress that is wearable with high flexibility and fulfills wearers' functional (e.g., comfort, mobility, ease of donning and doffing), expressive, and aesthetic needs. For this textile innovation challenge, incorporating various design technologies (3D printing, CLO, and Rhino), the flowy dress, *Bouncing with 3D Printed Soft Cells*, was proposed using the FDM method of 3D printing with TPU materials.

Aesthetic properties and visual impact. With the consideration of wearers' needs and desires, we incorporated Lamb and Kallal's (1992) functional, expressive, and aesthetic attributes into this design. As shown in Figure 1, this dress, *Bouncing with 3D Printed Soft Cells*, is consisted of 88 individual panels with various shapes and sizes. The inspiration of these distinct panels was derived from the concept of biological cells, which are basic building blocks of the human body. Certain cells in our body are self-renewal and they can differentiate themselves into other cell types (Stanford Children's Health, n.d.). We interpreted this phenomenon as the endless diffusion of technological innovation in our society. Each soft cell panel was designed to fit the human body nicely, allowing the 3D printed dress to conform in response to wearers' body movement without such a restriction. The textile structure in each panel was developed, referenced by

Figure 1. 3D printed soft cell panels

Pattinson et al.'s (2019) 3D printed textiles. The continuous lattice structures of 3D printed textiles, mimicking a traditional see-through fabric, can maximize wearers' functional needs by allowing the dress to be stretched in multiple directions. The dress with white TPU filaments and wave shapes of the panel edges reflects the image of bio-rhythm, transparency, and diffusion of technological innovation.

Figure 2. 3D prototyping

Process, technique, and execution. The dress, *Bouncing with 3D Printed Soft Cells*, involves multiple design steps: design ideation and sketching, 3D textile structure development and testing, 2D pattern development and 3D prototyping, mapping structured textile panels within a virtual prototype, 3D printing, and assembly. 2D patterns of the dress were first created and then virtually draped, stitched, and adjusted on a size 8 avatar in CLO (see Figure 2). The contour of 3D simulated dress was exported, which was then imported and used in Rhino for segmenting the dress into 88 cell-shaped panels as shown in Figure 1. Rhino was also used for developing the continuous lattice structured 3D textiles; all panels were extruded with a thickness of 0.4mm, which is the outcome of multiple iterations from testing 3D printed textiles' functionality as wearables. One of the FDM 3D printers was used to print 88 panels using TPU filaments, which is a common engineering material for FDM printers with high flexibility (Formlabs, n.d.). A total of 85 hours were spent creating this dress, including 79 hours of 3D printing and 6 hours of assembly. All panels were assembled together using a non-toxic, lightweight fabric adhesive. 3D printed button closures were added on the side seam and two shoulder panels for wearers to easily put on and off the dress (see Figure 3). This dress, *Bouncing with 3D Printed Soft Cells*, is extremely light with a weight of 387.9g, which would eventually enhance wearers' comfort, movement, and functionality.

Figure 3. 3D printed button closure

Cohesion. This design, *Bouncing with 3D Printed Soft Cells*, is the outcome of our 3D printed textile innovation challenge to develop 3D printed dress that is wearable as traditional fabrics and fulfills wearers' functional, expressive, and aesthetic needs. With the inspiration from biological cells and how they function within the human body, this design portrays the endless diffusion of technological innovation we do face in our everyday life. The flared dress with a simple silhouette was ideal for experimenting with drapes and flows of 3D printed textiles on the avatar and human body. Drapes between the 3D simulated dress in Figure 2 and our 3D printed dress were almost identical. The continuous lattice structures of 3D printed textiles maximize wearers' comfort, movement, and functionality. The dress is a true reflection of the diffusion of technological innovation and presents the future of 3D printing in wearable apparel design.

Significance, rationale, and contribution. By utilizing various design technologies (Rhino, CLO, and 3D printer) in 3D textile structure development, 2D and 3D prototyping, and dress production, this design was created to experiment with its wearability, considering wearers' functional, expressive, and aesthetic needs. Fabrics were developed as mesh-like 3D printed textiles with high flexibility and a lightweight, which allow the dress to be stretched in multiple directions. Through the textile innovation challenge, we showcase the potential of using the FDM method of 3D printing with TPU filaments for wearable apparel design.

Originality and innovation. This 3D printed wearable dress is original and innovative in terms of (a) textile innovation of developing 3D printed functional textiles for wearables, (b) creating wearables with 100% of 3D printed panels without using any other traditional fabrics, and (c) proving the potential to use FDM 3D printers with TPU filaments for wearable apparel design.

Date Completed: May 17, 2021

References

Chen, C. (2020). Vanishing ice. *International Textile and Apparel Association Annual Conference Proceedings, 77*(1). https://www.iastatedigitalpress.com/itaa/article/id/11743/

Cui, T., & Sun L. (2018). Hybrid comfort: 3D printing interwoven. *International Textile and Apparel Association Annual Conference Proceedings, 75*(1). https://www.iastatedigitalpress.com/itaa/article/id/1311/

Formlabs. (n.d.). *FDM vs. SLA in 2020: Compare the two most popular types of 3D printers*. https://formlabs.com/blog/fdm-vs-sla-compare-types-of-3d-printers/

Kim, S. G., Song, J. E., & Kim, H. R. (2019). Development of fabrics by digital light processing three-dimensional printing technology and using a polyurethane acrylate photopolymer. *Textile Research Journal*, *90*(7-8), 847-856. https://doi.org/10.1177/0040517519881821

Lamb, J. M., & Kallal, M. J. (1992). A conceptual framework for apparel design. *Clothing and Textiles Research Journal*, *10*(2), 42-47. https://doi.org/10.1177/0887302x9201000207

Lee, Y. A., & Kwon, Y-M. (2017). Internal peace in life. *International Textile and Apparel Association Annual Conference Proceedings, 74*(1). https://www.iastatedigitalpress.com/itaa/article/id/1696/

Nervous System. (2014). *Kinematics dress*. https://n-e-r-v-o-u-s.com/projects/sets/kinematics-dress/

Pattinson, S. W., Huber, M. E., Kim, S., Lee, J., Grunsfeld, S., Roberts, R., … Hart, A. J. (2019). Additive manufacturing of biomechanically tailored meshes for compliant wearable and implantable devices. *Advanced Functional Materials, 29*(32), 1901815. https://doi.org/10.1002/adfm.201901815

Stanford Children's Health. (n.d.). *What are stem cells?* https://www.stanfordchildrens.org/en/topic/default?id=what-are-stem-cells-160-38

Sun, L. (2017). Daring to sprint: 3D printing textile. *International Textile and Apparel Association Annual Conference Proceedings, 74*(1).

https://www.iastatedigitalpress.com/itaa/article/id/1738/
Sun, L. (2018). Instilled: 3D printing elastic lace. *International Textile and Apparel Association Annual Conference Proceedings, 75*(1). https://www.iastatedigitalpress.com/itaa/article/id/1355/
Sun, L., & Parsons, J. L. (2014). Accessing axis. *International Textile and Apparel Association Annual Conference Proceedings, 71*(1). https://www.iastatedigitalpress.com/itaa/article/id/2957/
Uysal, R., & Stubbs, J. B. (2019). A new method of printing multi-material textiles by fused deposition modelling (FDM). *Tekstilec*, *62*(4), 248-257. https://doi.org/10.14502/tekstilec2019.62.248-257
Valtas, A., & Sun, D. (2016). 3D printing for garments production: An exploratory study. *Journal of Fashion Technology & Textile Engineering*, *4*(3). https://doi.org/10.4172/2329-9568.1000139