Digital Waves

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Contextual and concept statement. 3D printing (3DP) revolutionized the traditional subtractive manufacturing process for producing intricate and personalized products, especially in the fashion industry (Kim et al., 2019; Spahiu et al., 2020). However, the applications of 3DP in fashion have been still limited to fashion accessories and footwear, mostly because of the material restrictions (Xiao & Kan, 2022). 3D printed textiles often lack essential material properties for wearability (e.g., drapability, stretchability), which fail to provide sufficient functional values to wearers (Lee, 2022). For example, Nervous System (2014) developed a conceptual dress with interlocked panels using rigid nylon 3DP filaments, which limits to satisfy wearers' ergonomic needs. Although previous studies have examined different textile structures using various 3DP methods and materials for developing 3D printed textiles with wearability in mind (e.g., Beecroft, 2019; Chen, 2022; Cui & Sun, 2018; Lee & Li, 2022; Sun, 2018; Zhang & Holland, 2017), little attention has been given to (a) create flexible 3D printed textiles with multiple color and pattern combinations to simulate traditional lace fabrics and (b) explore the seamless joining method between traditional fabrics and 3D printed textiles considering the wearables' functionality. Thus, we were challenged to develop the 3D printed dress, *Digital Waves*, that offers users better wearability by using both 3DP and digital textile printing.

Aesthetics. The design, *Digital Waves*, was inspired by constantly flowing ocean waves which symbolize harmony and connection and is the outcome of our reiterative design experiments to integrate 3D printed textiles with digitally printed traditional fabrics for the wearable product development. The fluid silhouette of the dress with a flattering shape amplifies the flowy effect of the design and offers wearers with ease of movement. The special ripple auxetic structures, consisting of multiple curve lines that emanate from central points, were embedded within 3D printed textiles, representing the undulations on the water surface (see Figure 1). With the flexible thermoplastic polyurethane (TPU) filament and the unique ripple auxetic structure, 3D printed textiles can contribute to functionality and wearability of the design by providing users with sufficient flexibility, stretchability, and drapability. The top of the dress comprises both traditional fabrics digitally printed with realistic flowing waves in ocean and 3D printed lace textiles with varied blue ripple motifs which reflect the design concept of unity and reconciliation. The bottom of the dress contains an additional 3D printed layer with a longer length overlaying on the digitally printed skirt. This partial concealing effect visually creates textural variations, color contrasts, and dynamic silhouettes. The yellow and white undulant ripple structures embedded in the dress bottom

Figure 1. The ripple auxetic structure textile

illustrate the movement of ocean waves rolling onto the beach, which evokes a sense of beauty and serenity from wearers. The 3D printed buttons with the LEGO structure on the dress side serve as the closure, which provides better accessibility and allows wearers to easily don on and off the dress.

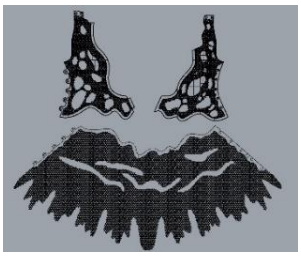

Figure 2. The 3D model of the dress in Rhino

Process, technique, and execution. The design started with the concept ideation, sketching of the dress, and the development of auxetic textile structures for 3DP and surface design for digital textile printing. Different textile patterns with various auxetic structures were tested using different 3DP materials and the textile pattern arrangements were examined and determined. In addition, different joint methods (e.g., seamless adhesive joining approach, sewing technique) were experimented for joining 3D printed textile panels and assembling 3D printed textiles with traditional fabrics. All 2D patterns were first developed, manipulated, and simulated on a size 8 female avatar in CLO 3D. The final contour lines then were imported into Rhino to create the 3D dress models for 3DP. The 3D printed part of the dress was segmented into 26 panels and the ripple structure patterns were inserted into each panel continuously (see Figure 2). The 2D patterns to be used in digital textile printing were adjusted and the realistic flowing wave prints were embedded into the 2D engineered patterns, using Adobe Illustrator. The fused deposition modeling (FDM) printing method was used to fabricate all 3D printed panels with while, yellow, and blue TPU filaments, separately. The seamless adhesive joining method used by Lee and Li (2022) was adopted and applied to manually assemble all 3D printed panels with various color combinations. A total of 40 hours was used to print all 3D printed panels and 8 hours were spent to trim and assemble each panel. Using the transfer digital textile printing technology, realistic ocean wave prints were first printed on the transfer paper with dye sublimation inks and then, transferred to the stiff mesh 100% polyester fabric with a heat press at 400°F (see Figure 3). A total of 7 hours was spent on sewing the 3D printed textiles with the digitally printed fabrics, using both machine and hand sewing techniques. A seam allowance with 0.25” was used to sew the 3D printed textiles and traditional fabrics together, while a 0.5” seam allowance was used for the parts with less curvature. Interfacings were attached underneath the digitally printed fabrics to provide the neat finishes for the wavy neckline, hemline, and armhole.

Figure 3. The dress with digitally printed ocean waves

Cohesion. The inspirations from flowing ocean waves and ripples on the water amplify the elegance of the dress and evoke the wearer’s sense of beauty and peace, which also demonstrate the design concept of reconciliation. With the application of a seamless adhesive joining method and sewing techniques, we successfully assembled the 3D printed textiles with the digitally printed fabrics, which lead to the significant improvement in wearability. By integrating various

colors of flexible TPU filaments with retracted auxetic structures, this dress not only fulfills users' unique expressive and aesthetic needs but also maximizes their comfort and functionality.

Contribution. With the limited material choices, 3D printed textiles often lack essential material properties that conventional textiles equip. Our design challenge and solution presented in this dress bring new possibilities for developing 3D printed wearables with the significant wearability enhancement. With the integration of innovative design technologies, our design is unique and original at (a) developing 3D printed textiles with various color and pattern combinations using the FDM 3DP method to mimic traditional lace fabrics and (b) successfully assembling 3D printed textiles with digitally printed traditional fabrics by combining a seamless joining method and sewing techniques for expanding the true wearability of 3D printed wearables.

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