Embellished Modularity

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In recent years, 3D printing technology rapidly gained notoriety by apparel designers due to its ability to create customized shapes while using less material than traditional manufacturing methods to develop the textile products (Dehgani & Goyal, 2022). Though designers have explored 3D printed garments using computer generated digital fabrication, the creativity once associated with handmade objects is removed in the digital process. A book titled Digital Handmade: Craftsmanship and the New Industrial Revolution by Lucy Johnston (2015) presented a series of designs and artwork created by international designers and artists who combined the precision of computing and digital fabrication offered by 3D printers with the skill and tactility of the artisan using different techniques to create unexpected objects. Thus, the researcher was challenged to develop a 3D printed design by combining one of the digital handmade techniques, 3D pen sketching. The 3D pen was invented in 2012 to provide affordable and simple ways to 3D print for hobbyists and artists (Manufacture3D, 2018). 3D pens create objects through melting the filament in a heated nozzle, similar to the principles used in FDM 3D printers. However, 3D pen operation is a more handmade process since the pen is controlled by the makers in speed, temperatures, and directions, much like an ordinary glue gun (Oliveira et al., 2020). Japanese designer Seiran Tsuno hand-crafted designs used the 3D pen and Polylactic acid (PLA) to develop exaggerated and colorful art forms (Typepad, 2020).

Creative designs combining 3D printing and 3D pen with flexible materials is still limited. Flexible and elastic 3D printing materials such as thermoplastic polyurethane (TPU) filament provides designers unlimited opportunities to explore fabric-like textures for creative designs (Lee & Li, 2021; Sun, 2018). Additionally, as most FDM printers have limited printing bed size, adhesives are often used to assemble smaller pieces of printed materials together to form a larger size textile. Previous studies by the researcher have explored modular designs which are formed by slotting together pieces of modular textiles to create garments without sewing. Therefore, the purpose of the design research was 1) to explore a new digital handmade technique by merging the state-of-the-art tools, 3D printer and 3D pen, into one design, and 2) to combine modularity with 3D printing technologies with flexible filament to create a wearable design.

The inspiration for this design originated from embroidery hoop art, which has grown in popularity in recent years. Rather than focusing on the embroidery itself and using the hoop as part of the process, Embroidery hoop art highlights the craftsmanship and process behind the

piece through displaying both the embroidery and hoops as wall art (Bettelley, 2018). Similarly, in this design, the process of the 3D pen sketching was highlighted on each of the 3D printed modular hoops and displayed on the body using a modular concept by interlocking the pieces together to form a digital textile. The motifs used in this design is a floral and botanical theme, representing the beauty of the handmade process while providing irregular textures, in contrast with the smooth and uniformed 3D printed modular hoops. A 3D printed modular skirt was created to finish the ensemble.

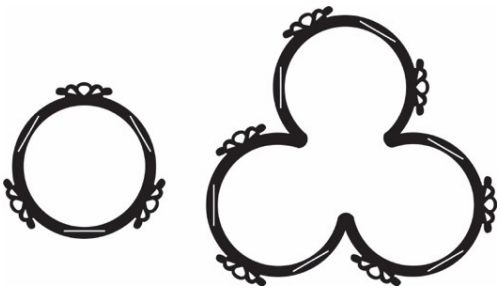

Figure 1. Module Hoop I and Module Hoop II.

The process for creating this design started by designing the modular hoops on Adobe Illustrator. A circle was used as the base of the module to mimic the embroidery hoops from the inspiration. A tab design was created to represent the adjustment hardware on an embroidery hoop. Three tabs were added on the outer edge of the circle along with three opposite slots on each module forming a hexagonal position to add functionality, forming the Module Hoop I. In this case, the circle modules can be interlocked together forming a textile using the tabs and slots. Three joined circle modules were designed by interconnecting three Module Unit I pieces. This enabled a larger sized Module Hoop II to be used for creating the design while maintaining equal tab and slot size for interlocking (Figure 1). Once the shapes of the two module units were finalized in Adobe Illustrator, the shapes were then imported in Tinkercad, an online 3D modeling program, to create the 3D models. A slicing application called Cura was used to convert the 3D models into several thin layers suitable for 3D printing. A FDM 3D printer was used to print a total of 21 Module Hoop I and five Module Hoop II pieces using a white TPU filament.

Next, a 3D pen was used to add the inner motifs based on hand drawings of wildflowers and butterflies. Different hand drawings suitable for the size of the Module Hoop I were created beforehand on paper. They were then laid under a transparent glass sheet as a template for 3D pen sketching. A mesh pattern was also created and printed out on paper for the Module Hoop II. A 3D pen was used to extrude the melted TPU filament within both module hoops on top of the glass sheet based on the premade drawings. To create the bust shape on two of the modules, a round wine glass was adopted as the "mold" for the base (Figure 2). The outer edges of each motif were joined with the 3D printed module hoops using abstract filament lines from the 3D pen. Once the 3D pen sketching process was completed,

Figure 2. Bust module.

each of the module unit was gently peel off the glass and draped on a dressform to create the top. By joining the tabs and slots on the module units, the top was created without the use of any adhesive or sewing machine. A 3D printed skirt with a geometrical waving pattern, mimicking the mesh pattern used on Modular Hoop II, was printed on the FDM 3D printer with the same TPU filament. The skirt consisted of five modular panels that used the same tab and slot designs from the top.

This design achieved the goal of exploring an innovative way of using digital technologies to enrich traditional hand techniques by creating a wearable ensemble with 100% 3D printed textiles without using any other traditional fabrics. In this design, the 3D pen generated the classic imperfections of handmade textiles while the 3D printer created the flawless shapes needed for the structure of the garment. In fact, the marriage of 3D printing and 3D pen represents creative intelligence and skill in making went together. In addition, the modular concept allowed the design to be customizable by altering the placement of the modular hoops. The integration of 3D printing technology into modular design allows for easy configuration and editing of designs while increasing the module design's durability, as the 3D printed modules' interlocking ability can stay functional over numerus actions of connecting/disconnecting. The design adds knowledge to the potential to use FDM 3D printers and 3D pen with TPU filaments for modular designs.

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