Modularity in 3D Printed Backpack

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

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Contextual Review and Concept Statement. Today's fashion industry is on the fast track, and fashion accessories such as shoes, bags, and jewelry are considered as one of the signature personalizing items (Cimatti et al., 2017; Shahbandeh, 2021). Mass-produced, standardized backpacks are not often designed to meet each user's specific ergonomic/functional, expressive, and aesthetic needs. Nowadays, it is crucial for fashion brands to consider wearables' customizability while developing new products. Modular design, interchangeably called modularity in design, is an emerging trend in product design that has a significant potential to facilitate its personalization and multi-functionality (Huang et al., 2012) but has not been widely adopted by product designers. Modular design allows a product subdividing into individual modules replaceable and interchangeable to maximize users' personalization, which is similar to the idea of LEGO creation (Gu et al., 1997). The modular design also leads to the extension of product lifespan by creating diverse new designs with existing modules based on users' imagination (Gershenson et al., 2003; Scheidt & Zong, 1994; Tsai, 2006).

3D printing, one of the innovative manufacturing technologies allowing designers to create personalized and customizable wearables, has attracted increasing attention from designers and product users in recent years (Ota et al., 2017). Several designers (e.g., Chen et al. 2017; Sun & Starkey, 2018) experimented with creating accessory bags using 3D printing; however, little attention was given to explore a novel sustainable design solution for advancing its personalization to meet users' multiple needs by incorporating various design technologies. Thus, we challenged to develop a 3D printed modular backpack that both satisfies consumers' unique desires and promotes their sustainability practices through its multi-functionality. For this challenge, this experimental design, *Modularity in 3D Printed Backpack*, is proposed through integrating various design technologies.

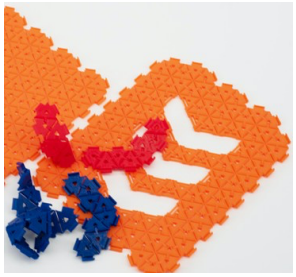

Figure 1.
Modular panels

Aesthetic Properties and Visual Impact. By utilizing a modular design approach, this 3D printed backpack can transform into different sizes of backpacks, handbags, or shoulder bags. Each 3D printed modular panel could be assembled in multiple ways, allowing users to create their personalized bags. As shown in Figure 1, we also created the imprint part of the bag with various colors, which provide more personalization options. Users can customize and replace the patterns with various

colors in the imprint frame. With the maximum level of personalization, Modularity in 3D Printed Backpack allows users to customize their backpack design based on their preferences and needs, especially fulfilling their ergonomic/functional, aesthetic, and expressive needs.

Process, Technique, and Execution. The design, *Modularity in 3D Printed Backpack,* involves multiple steps: design ideation and sketching, 3D body scanning of a wearer, CAD modeling, 3D printing, and assembly. The bag was designed and created considering users' ergonomic body shape and its multi-functionality. As shown in Figure 2, a portable structure scanner was used to capture the torso area of the human body, which was the foundation for the human CAD model to develop the ergonomically designed backpack CAD model in Rhino. Multiple iterations of CAD modeling were done for modularity in our backpack design. The triangular shape module interfaces were created, referenced by Nervous System's (2013) Kinematics concept, which consists of repeated interlocking triangular shape panels with moveable conical hinges. Each panel has an identical size of 18mm for each of three sides with a 3mm thickness. This backpack consists of various modular panels, including frames for one base, front and back, two sides, two replaceable imprints, and one top cover, two connectors, and two adjustable straps.

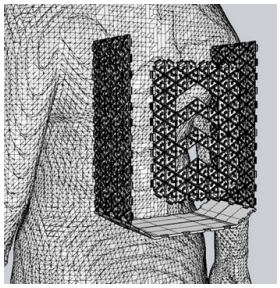

Figure 2. Body scanning and CAD Modeling

Figure 3. 3D printing and assembly

All panels were printed using Rasie3D Pro 2L, the fused deposition modeling (FDM) 3D printer. Polylactide (PLA) filaments, which are biodegradable and produced with renewable resources (Wijk & Wijk, 2015), were used for 3D printing. It took around 115 hours to print all 3D interlocking panels. All parts were then assembled together (see Figure 3). The interchangeable modules allow the design to transfer from a backpack to a handbag or a shoulder bag to fulfill users' different needs with high multi-functionality, leading to extending its lifespan.

Cohesion. With the integration of various design technologies (body scanning, CAD modeling, and 3D printing) and the use of a modular design approach, this 3D printed backpack not only fulfills users' ergonomic/functional needs but also allows them to create their personalized design to satisfy their expressive and aesthetic needs. The detachable 3D printed panels can be used in transforming to various bag styles, which maximize its customizability and lifespan. This design experiment showcases a true potential of the FDM printer using PLA filaments for the novel customized product design at the commercial level.

Significance, Rationale, and Contribution. Modularity in design is an emerging trend in product

design. As of now, modularity in fashion accessories design for its customization with multi-functionality has not been fully explored. Thus, we challenged to propose an innovative transformable backpack, integrating a modular design approach with various design technologies. Our design challenge presents a true potential of using 3D printing for customizable fashion accessories design and development in our digital transformation era.

Originality and Innovation. With the advancement of 3D printing, many fashion brands started to adopt 3D printing in their product design and development; however, the potential of 3D printing in designing wearables is still limited. Our 3D printed backpack is the outcome of exploring the potential use of 3D printing in modular fashion accessories design and development.

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