Exploring effectiveness of Programs and Tools for 3D Printing Wearable Product

Lushan Sun, Auburn University, USA
Jean Parsons, University of Missouri, USA

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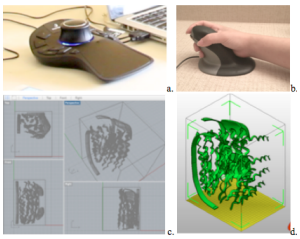
Due to the rapid adoption of digital fabrication technologies, such as 3D printing (3DP), the textile and apparel industry is recognizing the unique advantage of efficiently prototyping complex objects for various customized products (Lipson & Kurman, 2013). In the current textile and apparel industry, 3D computer-aided design (CAD) or computer-aided manufacturing (CAM) programs, such as OptiTex, have been limited to digitizing 2D flat pattern and virtually simulating fabric drape for garment design using body scan data. However, such programs only allow evaluation of a visual product representation. In the case of 3DP, or the process of converting a CAD model to physical prototype, efficient 3D modeling process is essential in product development. Today, 3D apparel design pioneers have been trained in mostly hands-on practice in traditional studio. Thus, they lack the knowledge in 3D CAD and are often collaborating with 3D CAD experts in 3D printing products. More importantly, the most popular 3D CAD software, such as Solidworks and Google Sketchup, are programed for users from engineering and architectural fields. They are more useful for structural or rigid object development and at the same time lack intuitive features suitable for traditional apparel designers and products (Sun & Parsons, 2014). Many 3D CAD practitioners today also use computer-based devices, such as a 3D mouse, to allow efficient object moving in six degree of freedom (6DOF), or free rotation of 3D objects on three different axes. Further, many of these 3D CAD programs are not the ideal one-stop shop for wearable product prototyping when integrating additive manufacturing. Thus, supplementary 3D CAD programs are often needed to evaluate object component layout for the final 3DP process. The goal of this research was to investigate the effectiveness of popular 3D CAD programs and tools for the traditional apparel designer in wearable product prototyping. Through conducting a design case study, this research examined the following research questions: 1) how do the capabilities or components of the 3D modeling program, Rhinoceros (Rhino), and 3D mouse by 3DConnexion aid the design process of a wearable product using a human avatar and the computer-based device, and 2) how do the capabilities of Rhino and the 3DP enhancement application, Netfabb, affect the design process for 3DP wearable products?

This research followed the naturalistic inquiry approach and research through design methodology in conducting a firsthand exploration of 3D CAD wearable product development. Data collection methods followed the reflective practice concepts, or reflect-in-, -on-, and –for-action. A reflexive journal was used to purposefully document reflective thinking and challenge or problem encountered during the CAD process. Also, computer screen recording was used to capture the 3D modeling process in Rhino, and video recording was used to capture the apparel designer's bodily behavior using the 3D mouse in the physical design studio. For the 3D



modeling process in Rhino, the 3D mouse was utilized in the left hand, and an ergonomic mouse was controlled by the right hand with a laptop computer (Figure 1.a-b.). Rhino was used for garment component slicing and layout, and Netfabb was used in the final evaluation for 3DP (Figure 1.b-c.). A misses size 8 body scan was converted into an avatar.

The data first suggests that Rhino served as an overall user-friendly interface for 3D modeling of wearable product through its CAD tools organization, commend line feature for tool search, available CAD views, and display modes. Features such as the *gumball* tool were the most useful and enabled the limited attention paid to comprehending the at times complex 3D CAD environment. Further, the design efficiency in Rhino was supported by the active use of object duplication to avoid unnecessary repetition. Some of the objects in the developed basic format, such as curve or line, were saved as the foundational "patterns" for further complex form creation. Also, the use of lock and unlock functions aided the organization of the CAD space and supported the focus of objects exploration in specific situations. Second, the 3D mouse provided a natural sense of object exploration in six different directions with a very sensitive touch. Through allowing the mind to relax from focusing on comprehending the x-y-z coordinate environment when moving objects, it greatly reduced the disconnect between the physical world and the virtual design environment in Rhino. However, the designer's body still naturally needed to lean close to the computer screen when examining small spaces between objects and manipulating object curve. Third, the application of a human avatar was helpful in providing a silhouette that represented the general measurements of the body form but was difficult to define key body landmarks. In addition, the human avatar developed was not symmetrical and thus resulted some ill fit on one side of the body. Fourth, the Netfabb program may be useful for spatial visualization in further evaluating collision between components within a reference box to effectively use the 3DP building volume.

Overall, the findings suggest that the 3D CAD environment in Rhino may be utilized and interpreted as a virtual design studio to organize various objects as in the physical design studio, However, Rhino challenges the way an apparel designer interprets CAD tools in creating various complex forms and reconsider orders of operation in product development. Also importantly, 3D printing wearable product today may frequently require the effective integration of component layouts for limited space. Research limitation does exist in the Rhino use proficiency, the garment design, as well as the 3DP process and material utilized in 3DP. In future advancement of 3D CAD for 3DP, the lack of material evaluation and analysis features in 3D modeling need to be considered as the more critical disadvantage of 3D printing integration today.

Lipson, H., Kurman, M. (2013). *Fabricated: The new world of 3D printing*. Indianapolis: John Wiley & Sons, Inc.

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