Title: Alisa-Bra Design Using a Digital Workflow Combining Clo 3D and 3D Knitting
Keywords: Digital Knitting, Clo 3d, Bra, Functional Design

Krissi Riewe Stevenson, Kent State University

The purpose of this project is to improve the bra garment using an integrated workflow connecting 3D apparel design software with CNC (computer numeric controlled) digital knit software. The bra garment is in need of improvements to address fit, comfort, and production problems, and these technologies offer methods that can contribute to innovative solutions. This closely fitted foundation garment is challenging to fit correctly, and few people wear the correct size or style (White & Scurr 2012) The 3D volume for the bust is a critical component of correct fit, especially in relation to placement and shape of the underwire. (Coltman et al. 2018, Balach et al. 2020; McGhee and Steele 2011) Additionally, the traditional bra is made using complex pieces cut from textile yardage that cannot be nested efficiently, leaving waste; furthermore, construction is intricate involving use of specialized sewing machines. This makes production costly and prone to employ factories with unethical labor practices to reduce costs. (Kadlec 2019) These product challenges inspired the development of this workflow utilizing the benefits of 3D knitting and Clo 3d as technical digital tools to support creative use of material knowledge, allowing the designer to develop a more sustainable production process while improving comfort and fit using engineered textiles and 3D textile shapes.

This applied research follows a knowledge through practice framework (Bye 2010, Chen and Lapolla 2021), and builds on previous research transforming 3D shapes into 2D patterns for digital knit programming (Liu et al. 2021). It focuses on improving this process for apparel by incorporating the design software Clo 3d to provide 3D design and fit development while also converting traditional flat patterns to knittable shapes with integrated 3D geometry to capitalize on the capabilities of 3D knitting. Digital knitting offers the ability to produce innovative soft goods by allowing textiles to be designed and created with engineered material properties and 3D form, unlike cut and sew textile yardage. However, these capabilities are often lost between designers comfortable with cut and sew methods and the programming technicians. Additional knowledge and scholarship connecting digital knitting and apparel design processes is needed, (Gorea et al. 2021) and this research seeks to contribute to bridging that gap. For this bra design, the Stoll ADF-3 16-gauge knitting machine and accompanying proprietary programming software Create+ was used along with 3D design software Clo 3d to design a workflow of shape and textile structure development for a knitted bra garment. This opens space to develop integrated processes and workflows, (Sun & Zhao 2018) contributing to improvements in sustainability and efficiency. The incorporation of Clo 3d allows design creativity and fit development to be conducted digitally without consuming extensive resources (Campbell & Parsons 2004, McQuillan 2020), and digital knitting can produce exact 3D textile shapes, minimizing or eliminating waste with seamless support. Combined with specialized yarns, products can be developed with specialized textile

characteristics; in the case of the bra, support and compression can be engineered within specific areas of the bra.

Development of the bra began by analyzing the digital knitting process to determine knit direction; kitting vertically would be unnecessarily complex and time-consuming, while knitting horizontally offered a more streamlined approach. Additionally, because a knit textile is a one-way fabric, the bra would be best developed as two symmetric mirrored halves. To develop the material properties of support needed for this garment, extensive material and form sampling of a spacer structure was conducted. This structure allows the face and back of a textile to look and feel different by incorporating a front, back, and interior connecting yarn. By experimenting with

Figure 1

Figure 2

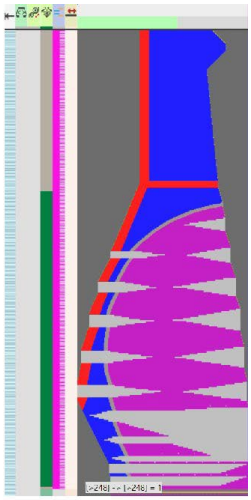

Figure 3

a variety of yarns and knit structures, the desired elasticity, compression, and loft were achieved using an outer yarn of silk, interior yarn of spandex, and back yarn of cotton-wrapped elastic. (Figure 1) A Clo cut and sew wired bra pattern was then transformed into a shape that could be imported into the digital knit software. In traditional patternmaking, opposing convex and concave shapes form curves designed to match the body's curves. However, knitting requires a yarn path to follow sequential rows of knit stitches. To create 3D shapes, these can be stacked in engineered areas to create the effect of opposing convex shapes in a process called goring or "partial knitting" (Liu et al. 2021). For the bra, the high point of these stacked rows must follow the horizontal high point axis of the cup, which is centered on the cup and curved to the center of the band. To convert the cut and sew pattern slashes were made in parallel rows to this line determining the placement of goring. Additional measurements B, C, and D were used to establish the vertical lengths, ensuring correct cup volume, depth, and underwire placement. (Figure 2) This final gored pattern shape was converted to a jpeg for import in to the Create+ software, and dimensions calculated using the textile structure samples to determine number of stiches in width and height. The file was completed by applying the desired spacer structures in specified areas and adding

underwire channel, stitch tension, start and finish, and narrowing and widening information. Aesthetic detail was added using tucks in a floral pattern along the bra cup edge. (Figure 3) This completed file was mirrored and both sides knitted. These two halves were finished by stitching at center front and attaching hook and eyes and straps.

This resulting garment represents successful use of this integrated tool and material workflow in the development of a bra that has a comfortable textile property and well-fitted 3D shape while using a more sustainable production process. The final product is the direct result of knowledge of both materials and the digital tools, well as an understanding of the knit process to construct a garment that, rather than rely on traditional ideas of flat patternmaking, utilizes "inherent potential in conceptualizing techniques as thought processes and systems (Lehmann 2012 p.155-156). Future work includes material and structure explorations to develop additional engineered textiles as well as explore use of the measurement axis in Clo 3d to develop a grading process. The improved efficiency and sustainability of this integrated workflow has been shown to be successful for a bra and can be expanded on and applied to a variety of soft goods products.

References:

Balach, M., Cichocka, A., Frydrych, I., & Kinsella, M. (2020). Initial Investigation Into Real 3D Body Scanning Versus Avatars for the Virtual Fitting of Garments. *Autex Research Journal*, *20*(2), 128–132. https://doi.org/10.2478/aut-2019-0037

Bye, E. (2010). A Direction for Clothing and Textile Design Research. *Clothing and Textiles Research Journal*, *28*(3), 205–217. https://doi.org/10.1177/0887302x10371505

Coltman, C. E., Steele, J. R., & McGhee, D. E. (2017). Which Bra Components Contribute to Incorrect Bra Fit in Women Across a Range of Breast Sizes? *Clothing and Textiles Research Journal*, 36(2), 78–90. https://doi.org/10.1177/0887302x17743814

Chen, C. and Lapolla, K. (2021). The Exploration of the Modular System in Textile and Apparel Design. *Clothing and Textiles Research Journal*, 39(1), 39-54. https://doi.org/10.1177/0887302X20937061

Gorea, A., Baytar, F., & Sanders, E. A. (2021). Challenges and design opportunities in prototyping seamless knitted apparel: a case study. *International Journal of Fashion Design, Technology and Education*, *14*(2), 127–138. https://doi.org/10.1080/17543266.2021.1881170

Kadlec, J. (2017). "You Are What You Buy: The Moral Paradox of Ethical Lingerie." *The Lingerie Addict,* June 12 2017. https://www.thelingerieaddict.com/2017/06/the-moral-paradox-of-ethical-lingerie.html

Lehmann, U. (2012). Making as Knowing: Epistemology and Technique in Craft, *The Journal of Modern Craft*, 5:2, 149-164. https://doi.org/10.2752/174967812X13346796877950

Liu, S., Mao, S., & Zhang, P. (2021). Toward on integrally-formed knitted fabrics used for automotive seat cover. *Journal of Engineered Fibers and Fabrics*, *16*, 155892502110065. https://doi.org/10.1177/15589250211006544

McGhee, D. E., & Steele, J. R. (2011). Breast volume and bra size. *International Journal of Clothing Science and Technology*, *23*(5), 351–360. https://doi.org/10.1108/09556221111166284

McQuillan, H. (2020). Digital 3D design as a tool for augmenting zero-waste fashion design practice. *International Journal of Fashion Design, Technology and Education*, *13*(1), 89–100. https://doi.org/10.1080/17543266.2020.1737248

Parsons, J. L., & Campbell, J. C. (2004). Digital Apparel Design Process: Placing a New Technology Into a Framework for the Creative Design Process. *Clothing and Textiles Research Journal*, *22*(1–2), 88–98. https://doi.org/10.1177/0887302x0402200111

Sun, L., & Li, H. (2018). Technology disruptions: exploring the changing roles of designers, makers, and users in the fashion industry. *International Journal of Fashion Design, Technology and Education*, *11*(3), 362–374. https://doi.org/10.1080/17543266.2018.1448462

White, J. B., & Scurr, J. (2012). Evaluation of professional bra fitting criteria for bra selection and fitting in the UK. *Ergonomics*, *55*(6), 704–711. https://doi.org/10.1080/00140139.2011.647096