

**Title: Digital Workflow Merging 2D Patternmaking with 3D Knitting through Bra Design**

**Keywords: Digital Knitting, Clo 3d, Create Plus, Garment Fit, Functional Design**

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The purpose of this project is to establish best practices for connecting and integrating 3D apparel design software with CNC (computer numeric controlled) knit software through the prototyping of a 3D knitted bra. This research applies a knowledge through practice approach (Bye 2010), and builds on previous research on transforming 3D shapes into 2D patterns that can be used in digital knit programming (Liu et al. 2021). It focuses on improving this process for apparel designing by incorporating design software to provide 3D design and fit development, while also transforming traditional flat garment patterns to knittable shapes with integrated 3D geometry to capitalize on the capabilities of 3D knitting. Digital knitting is a growing technology capable of producing innovative soft goods products by allowing textiles to be designed and created with 3D form, unlike woven goods that must be cut and sewn. However, the opportunity to design integrated textile and form into soft goods is often lost between designers comfortable with cut and sew methods and technicians who conduct the programming. There is a need for additional knowledge and scholarship to connect the gap between digital knitting and apparel design processes. (Gorea et al. 2021)

For this project, Stoll CMS ADF-3 16-gauge and 7.2-gauge knitting machines and the accompanying proprietary programming software Create+ is being used in conjunction with the 3D design software Clo 3d to develop a workflow of shape and textile structure development for a 3D knitted bra garment. This opens space to develop integrated processes and workflows, (Sun & Zhao 2018) contributing to innovative approaches that can improve sustainability, agility, and efficiency. The incorporation of Clo 3d allows design creativity and fit development to be conducted digitally, making it a space for textile and design exploration without consuming extensive resources. (Campbell & Parsons 2004, McQuillan 2020) Digital knitting can produce exact shapes in both flat and 3D forms, minimizing or eliminating waste and providing seamless support. Combined with specialized yarns, a wide variety of 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. The bra garment is in need of improvements from both wearer comfort and environmental sustainability perspectives. It 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 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 a process utilizing the benefits of 3D knitting and Clo 3d to address comfort, fit, and sustainability.

The project began with a basic wired cut and sew bra pattern developed in Clo as a base to be converted to a knittable 2D shape that would produce the same shape and volume. In traditional patternmaking, opposing convex and concave shapes form curves designed to match the body's curves. However, digital knitting must occur in sequential rows of knit stitches; 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. This can be marked on the pattern pieces in Clo (Figure 1), or on a paper pattern taped together. (Liu et al. 2021). By cutting to this line, placement of the goring is determined. (Figure 2) Additional measurements B, C, and D were used to establish the vertical lengths, ensuring correct cup volume and depth. The shape is then re-drawn in a shape that appears to have many small darts along the top and bottom edge of the cup. These areas will not be knitted but will allow the fabric to grow in a 3D shape while the yarn can move in the required sequential stitch pattern. (Figure 2) Before knitting, the new shape can be sewn, adjusted in coverage or design, and fit checked in Clo. This shape can then be imported into Stoll's Create+ program to develop the knit file. While the program can import dxf files from Clo, gored pattern shapes do not import well, therefore, a jpeg image is used to import an outline of the shape. Using previously developed gauge swatches for the bra textile structures the jpeg can be imported with the proper number of stitches in width and height. This is then used to develop the program for the bra with correct textile characteristics, shaping stitches, and wire channel, and a first sample knitted. (Figure 3)

This process can be modified to create larger shapes, or even ones that cannot be cut and sewn efficiently. The process allows the



Figure 1

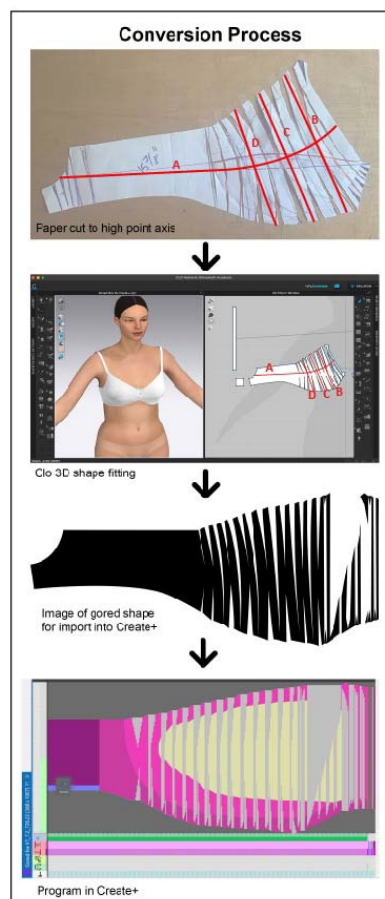


Figure 2

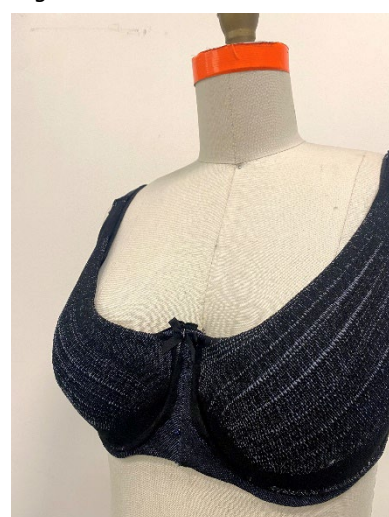


Figure 3

designer to use the benefits of establishing design, fit, and size in Clo 3D and develops a process for transferring this information into the Create+ software for complex 3D shapes. This eliminates considerable programming time to manually draw the gored shape in the correct size. Ongoing work will further improve the process and refine the resulting garment, as well as investigate the use of these measurement axis in the development of a customizable cup volume process. By establishing this more efficient and sustainable process of bra construction, it can be expanded upon and applied to fashion-forward designs and other types of products that rely engineered textiles and 3D shapes.

### 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>
- 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>
- 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>

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- 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, J., & 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>