3D bodies to flat patterns: A comparison of techniques

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Introduction: Current mass production techniques prioritize efficiency over fit. Production chooses to grade sizes from a selection of fit models rather than use the customer's body to develop patterns, a limitation that leads to insufficient fit (Krzywinski & Siegmund, 2017). Customer dissatisfaction with garment fit was exacerbated over the Covid-19 pandemic, as online shopping became normalized and reduced the ability to try on garments in-store (Bae 2022). The advent of 3D body scans and CAD software enables the exploration of the question - can we efficiently make flat patterns from three-dimensional (3D) surfaces (i.e., body)?

Patternmaking is fundamentally a question of geometry. This perspective on the technique allows for a more theoretical interpretation and development of new rules that can provide insight into making made-to-measure feasible at scale. The answer is a *map*, a function that can describe a change of coordinates, properties, etc., but in this context, it details a change in dimensional space. Common use includes texture mapping rendering color, shadows, and other details onto 3D objects in computer graphics. *Flattening* refers to the objective is to map a surface from 3D to 2D. In the context of pattenmaking, if there exists a 3D target surface then a flattening map can develop 2D patterns. Existing work on flattening focuses on developing patterns from anthropometric features with silhouettes encountered in traditional patternmaking. However, traditional silhouettes and seams do not approximate surfaces with complex curvature like the human body well (Delp & Thurston, 2011). This concept in conjunction with the growing prevalence of body scans prompts the question: does a process to derive patterns directly from the body result in a better fit than the "traditional" technique?

Methods: Shingo Sato's Transformational Reconstruction presented an analogous process for the study. The process to create a flat pattern from a target garment involved drawing the desired pattern (style lines), projecting them onto the target garment surface, and using the Boundary First Flattening (BFF) software developed by Sawhney and Crane (2017) to create a flat pattern. The target garment for this study was a knee-length mermaid skirt. This was a garment choice that was appealing to the participant, it was also chosen because it was straightforward to model due to its cross sections being simple closed curves (Figure 1a).

One female participant (aged 46, White, 5'2", 137lbs) was scanned using a Human Solutions Vitus[bodyscan] 3D body scanner. The watertight mesh was imported into Rhino and *contoured* in the z-direction (Sayem, et. al, 2012). The knee-length mermaid skirt stipulates that the skirt is form-fitting through the mid-thigh and then gradually flares so from the last contour at mid-thigh, ellipses were gradually scaled larger until the mid-calf landmark. To create ease, the curves were then *offset* from the body mesh .5". Thereafter, the *sweep* command was used to create the surface seen in Figure 1a. Long meandering style lines were drawn on a rectangle roughly the surface area of the skirt surface and *projected* to the target surface. Afterward, the target surface was *split*, creating four topological disks that comprise the *lava lamp pattern.* The BFF program maps curved disks to the plane to preserve boundary lengths and minimize area distortion for ease of manufacturability since adjacent seams must be the same length. Besides aesthetics, the long meandering style lines served to minimize area distortion by traveling through feature points. Another consideration for the design and placement of the style lines was ensuring that the pattern did not overlap and had enough space to add seam allowance.

For the *traditional skirt*, a skirt sloper set was developed for the participant following the Joseph-Armstrong patternmaking techniques. Then it was modified to fit the aesthetics of a knee-length mermaid skirt**.** The measurements used for drafting were extracted directly from the watertight mesh model. First, the frontal plane (side seam) was identified by the midpoint between the abdominal and buttock prominence points (Song & Ashdown, 2011). The sagittal plane was identified by drawing a plane that included both points in the set. These planes were used to *split* the contours that coincided with landmarks. The basic skirt sloper was drafted in Rhino and the 6-gore deviation was applied. Last, the pattern was tailored to achieve the knee-length mermaid skirt style in Browzwear VStitcher using the participant's body scan as a reference.

(a) (b) (c) (d)

Figure 1. (a) Knee-length mermaid skirt surface in Rhino, (b) Lava lamp patterns, (c) Lava lamp skirt scan, and (d)Traditional skirt scan

Results and Discussion: The biggest difference between the pattern pieces was the uniformity, the traditional patterns mirrored one another on the right/left sides of the body however the lava lamp pattern pieces had no symmetry (Figure 1b). Additionally, the long meandering seams were curvier and more challenging to construct compared to the straighter traditional seams. Fit evaluation was assessed by the female participant's comfort level trying on both the traditional and lava lamp skirt. Key elements were abdomen, hip, and waist comfort as well as garment drape. The *lava lamp skirt* fit well (Figure 1c); the participant noted she the skirt was comfortable around her protruding abdomen, a problem area for when trying on similar garments. She also expressed comfort in a wide range of motion and postures, the fit improved when she stood in the same posture as the scan. The application of uniform ease (1/2") through the garment did make the skirt a bit loose in some areas. It is possible that uniform ease is not an appropriate allowance for drafting directly from a body scan. Meanwhile, the *traditional skirt* was too tight (Figure 1d), and the participant struggled to get the skirt on and then was uncomfortable moving about in the skirt. Visible horizontal wrinkling across the front of the skirt supported the participant's feedback. There was a significant gap along the back waist, which the participant noted happened frequently when she shopped for skirts. The waist gap may be attributed to ambiguity in traditional drafting instructions for the sloper while the tightness may be an error in the tailoring process. The participant preferred the drape of the *traditional* skirt over the *lava lamp;* however, the drape can be easily fixed by altering the Rhino surface.

Conclusion: The present study aimed to compare the fit or distortion from the target surface of a traditional patternmaking technique versus a flattening technique in Rhino. The *lava lamp skirt* derived from the flattening technique proved to fit better on the female participant than the *traditional skirt.* However, the *traditional skirt* silhouette was more balanced and aesthetically pleasing because the *lava lamp pattern*s were very sensitive to construction errors. During flattening, slight misalignment of the seam can drastically alter the garment shape; therefore, it is imperative to have frequent notches on the pattern. Future studies should look at a more in-depth analysis of static and dynamic fit. Additionally, tracking how many prototypes of each pattern drafting process (flatten vs. traditional) would provide insight into the efficiency. Future work can include optimizing style line placement and features to improve fit, using an algorithm to generate style lines, and testing the flattening approach on more complex clothing models.

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