Generative pants pattern making for optimized fit in mass customization

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Background: Fit plays an important role in the style, comfort, and performance of the garment, and leads to the overall customer satisfaction (Kim & Damhorst, 2013). Accelerated by the Covid-19 pandemic, purchasing garments online without trying them on continues to be one of the main reasons of consumer dissatisfaction (Pookulangara et al., 2021). To improve consumers' fit satisfaction, the ideal solution would be to introduce a more segmented and expanded size system. However, such system would likely increase overall manufacturing costs (Xia & Istook, 2017). Mass customization (MC) , i.e., customizing garment fit and design based on individualized needs of consumers, has been proposed as a solution to satisfy the highly segmented and diversified market (Ashdown & Loker, 2010). It relies on technological advances to maximize the freedom in manufacturing with low costs, such as three-dimensional (3D) body scanning, 3D printing, and machine learning (Mpampa et al., 2010). One of the key factors deciding the efficiency of MC is the conversion of body measurements into 2D garment patterns by putting the measurements into certain pattern drafting formulas (McKinney et al., 2017) – often called parametric design. As one formula cannot accommodate all the body types (Song & Ashdown, 2012), even parametric pattern-making systems require iterations of additional input from skillful pattern makers with tacit knowledge and feedback from customers (Sohn et al., 2020). Generative design has been introduced to automate the iterative process (Krish, 2011). Once an initial input and goals are set, the algorithm generates multiple design variations, evaluates them, chooses the best one, and creates the next generation again (Li et al., 2020). Previous studies explored generative algorithms with neural networks to create designs (Rostamzadeh et al., 2018), but none of them considered their potential for fit optimization. Therefore, the current study aimed to explore the generative design techniques to create a fit-optimized 2D pattern for a 3D body model without using any pattern drafting formula. The algorithm focused on generating pants patterns, considering the larger dissatisfaction on pants compared to the upper garment.

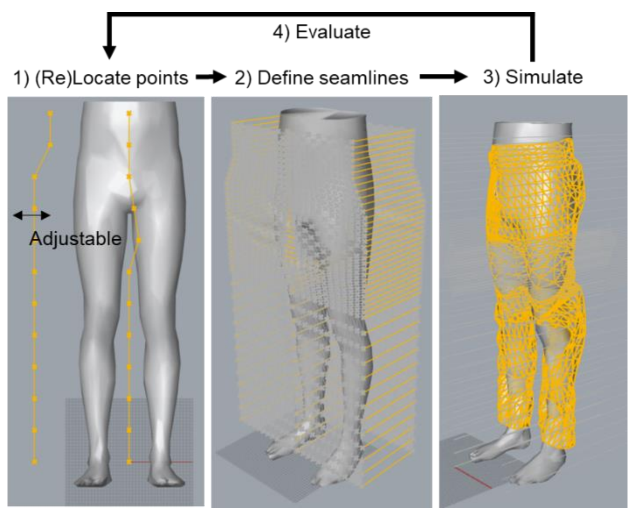

Figure 1. Generative pattern making system

Methods: A 3D graphic software Rhinoceros (Robert McNeel & Associates, WA) and its in-app tool Grasshopper were used to create a generative pants pattern-making system. A body scan of a male participant in minimal clothing was obtained by using a Vitus XXL 3D full-body scanner (Human Solutions GmbH, Germany). The proposed system followed the four steps for generative pattern making: (1) (Re) Locate points: For the initiation, the points were roughly located around the lower body. Each point could be adjusted horizontally. 2) Define seamlines: The points defined the pattern surface, and the relevant edges were connected as seamlines. 3) Simulate: Seamlines were stitched so that the pants pattern could be worn on the 3D body. 4) Evaluate: Based on the preset criteria (e.g., average distance between the body and the pants), the fit was evaluated. After the evaluation, the algorithm went back to relocate the points and to create a new pattern (Figure 1).

The system generated pants patterns based on the given 3D body to achieve goals including (1) minimum area difference between the body surface and the pants, (2) minimum area/length difference before/after worn on the body, and (3) minimum distance from the body surface to the pants (Figure 2a). The pattern set that met the goal best was chosen as the 'Test' pattern, whereas the other set of pants patterns drafted based on the Joseph-Armstrong's methods used as the 'Control' pattern (Joseph-Armstrong, 2009). Test and Control patterns were simulated and compared in a 3D garment simulation tool CLO 3D (CLO Virtual Fashion, Korea). According to a garment pressure measurement protocol (Brubacher et al., 2021), the strain of the pants on nine locations on the lower body was measured in CLO 3D.

Results: The generated pants patterns (Test) followed the basic morphology of pants patterns; however, they had a visibly narrower width overall and a longer crotch as compared to the Control (Figure 2b), which was confirmed by the key measurement comparison (Table 1). 3D garment simulations did not show a noticeable difference in appearance, due to the tightness of the Test patterns as digital patterns were stretching themselves in the software to fit on the avatar. However, 'fit map' function of the CLO 3D determined that it is impossible to wear the Test in some locations (Figure 2c). The measured strain of the Test was 1.88% higher than the Control on average.

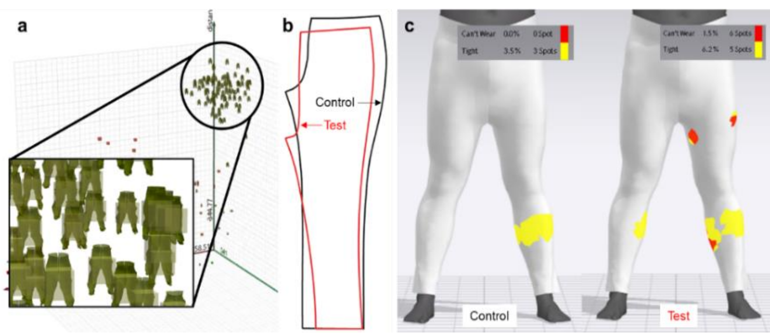

Figure 2. (a) Generated pants patterns, (b) Front pants pattern of Test and Control, (c) garment simulation and fit evaluation result.

Table 1. Key measurements of the 3D scanned body, Control patterns, and Test patterns.

Measurement [mm]	Body	Control				Test		
		Front	Back	Circum-ference	Ease	Front & Back	Circum-ference	Ease
Waist girth (Waistline)	934	224	235	920	-14	230	920	-14
Crotch length	648	266	276	542	-106	361	722	74
Side seam	971	995	990	N/A	19	954	N/A	-17
Inseam	737	752	750	N/A	13	611	N/A	-126
Ankle girth (Hemline)	236	203	221	425	189	154	308	72

Discussion: The current study introduced generative design techniques for pants pattern making and demonstrated its potential with limitations. The goals set in this study (e.g., minimum area difference between the skin and the pants) would be one of the main reasons why the Test became too tight to wear, which implies that setting the right goals is crucial to get the best results. Fit test with an actual textile would allow a better evaluation of the system. Automated garment pattern making with a minimal level of human intervention is indispensable for mass customization. It is expected that the generative design approach would be helpful for highly asymmetric bodies, which the common pattern drafting methods cannot accommodate.

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