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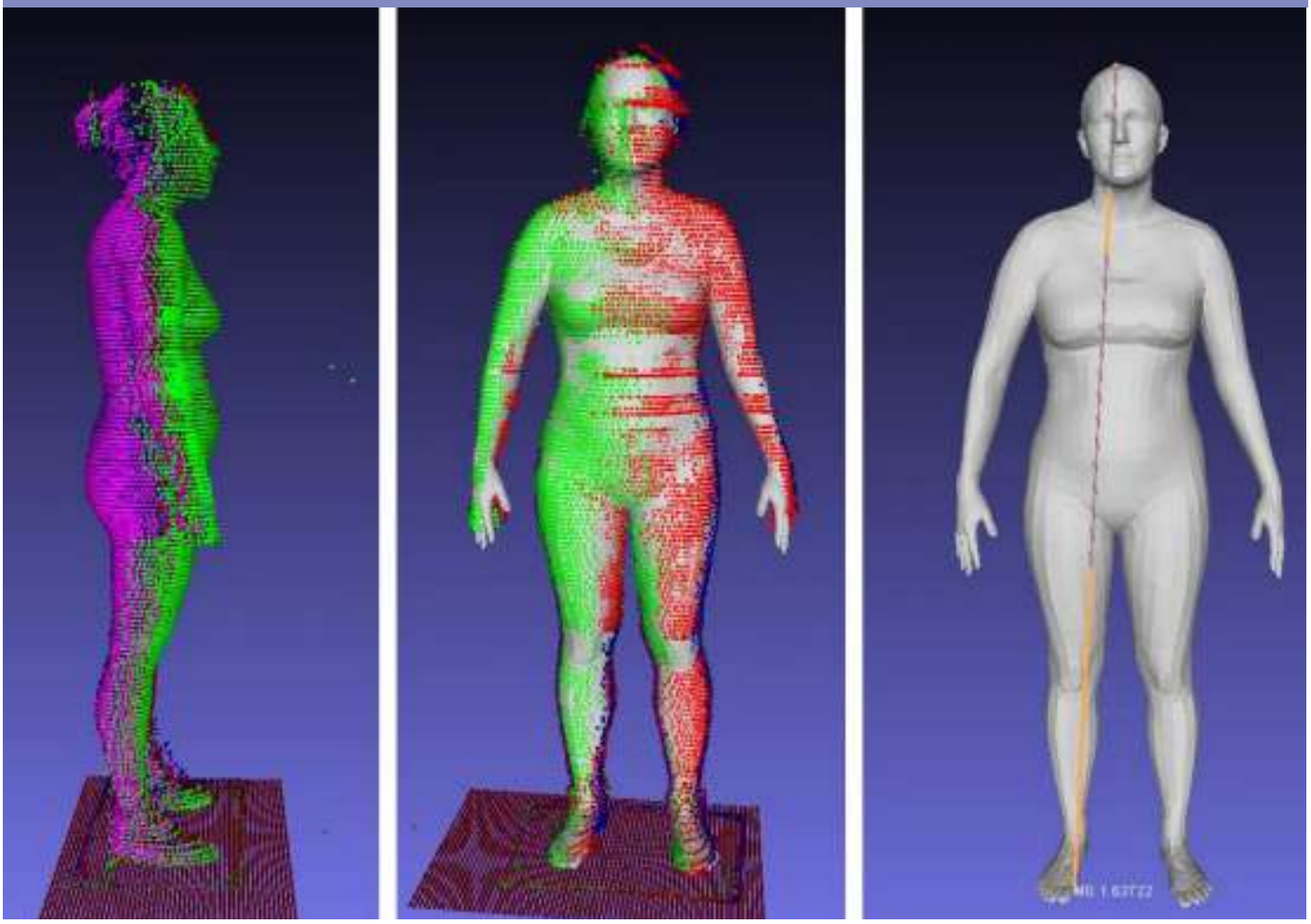


Figure 1. (a) Scanned human body point cloud data; (b) human body point cloud model after data pre-processing; (c) model for exporting human body data [6].

Beyond the Standard Pattern Block: Parametric Patterns for Diverse Anthropometric Variables in Custom-Made Clothing

In the clothing industry, pattern making is one of the critical tasks, it translates a fashion illustration into two-dimensional geometric shapes, which serve as a pattern template for constructing an accurately fitted garment. Most of the garment returns due to inability to use accurate pattern blocks. Conventional pattern making methodologies fail to effectively integrate diverse anthropometric variables into garment development. This article critically examines the limitations of conventional pattern-making approaches and explores how parametric and generative design systems can enable personalized apparel development.

Pattern drafting begins from scratch, create using specific body measurements, mathematical formulas, and geometric rules [1]. This approach is labour intensive, subject to inaccurate pattern development and incorrect fits. It is believed that pattern making is highly skilled techniques, and art which requires technical ability, and a sensitivity to interpret a design, with a practical understanding of garment construction. Domestic garment industries adopt manual pattern drafting methods, and large scale manufacturers adopt 2D CAD tools to create pattern drafts and develop production ready patterns using the extracted pattern blocks. Manual pattern drafts and blocks are developed

according to the published pattern making procedures, mainly Wilfred Aldrich [2], Armstrong [3], rely on a series of standard measurements and formulas based on average body types, therefore, they often fail to accommodate the unique body shapes of individuals. These patterns are considered as standard pattern blocks for defined wearer segment. The standard block patterns are made for average size and then two-dimensional linear grade rules applied to a static base block to obtain the other sizes. A 2D pattern operates strictly on a flat X-Y axis, while the human body exists in a highly complex, variable 3D space. Because the static base block assumes a single, standardized body shape, applying rigid 2D rules to accommodate diverse bodies inevitably leads to proportional distortion. Ultimately, traditional 2D pattern drafting and grading fail because they attempt to solve a three-dimensional spatial problem and finally garments are not fit on 3D human body shapes. Also, this approach is time consuming, labour-intensive and not convenient to store for future access.

The future of the fashion industry will increasingly focus on personalized garment development, driven simultaneously by shifting consumer preferences for individuality and rapid technological advancements in digital design [4]. In addressing the limitations of manual 2D pattern drafting, the apparel industry sought a digital strategy called Made-to-Measure (MTM) system to achieve mass customization. MTM was introduced to support Mass Customization and MTM systems have increased since the 2000s because of the growing inclination of consumers for customized clothing.

The MTM platforms allowed manufacturers to digitize their standard 2D base blocks instead of drafting a new pattern for every customer, these early algorithms were designed to take a wearer's basic linear measurements and automatically adjust to obtain the closest matching digital block. Made-to-Measure (MTM) systems work by applying localized mathematical adjustments to a pre-existing standard 2D pattern block based on an individual's linear body measurements [5], rather than generating a new pattern mathematically from scratch. In aligning with the mass customization business approach, MTM enables readily create customized clothing and link it to normal production lines. Nevertheless, MTM systems apply two-dimensional linear adjustments to a static base pattern, however they fail to account for the unique 3D spatial volume and postural geometry of the human body in creating the pattern piece geometry.

To overcome the limitations of standard 2D blocks, the state of the art in apparel engineering has shifted toward data driven pattern generation. In a data driven paradigm, a pattern is no longer a static pattern piece geometry, it enables dynamic, algorithmic, parametric pattern making. Rather than relying on simplified linear rules, these advanced CAD frameworks ingest massive, multi-variable datasets to compute the optimal garment geometry. This approach requires 3D body scanning technology, these scanners generate a high-resolution digital twin, a dense mathematical point cloud, that accurately maps the exact surface geometry, posture, and unique volume distribution of the individual wearer. By

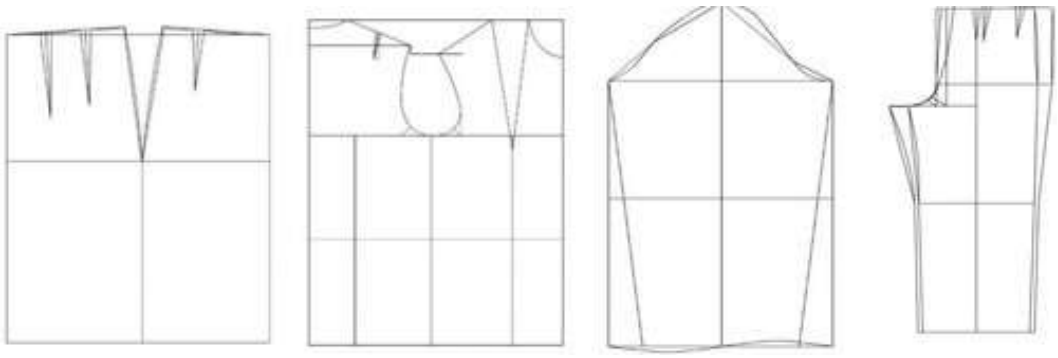


Figure 2. Pattern outputs of parametric approach [7]

feeding this data into parametric algorithms, the system can automatically generate and optimize custom 2D pattern pieces that are mathematically guaranteed to fit the specific 3D topology and functional requirements of the wearer, entirely bypassing the need for a traditional base block. Therefore, body scanned data based parametric pattern development can address the inefficiency and inaccuracies of manual anthropometric data based pattern development.

Beyond parametric pattern making, Generative Design approaches are emerging in pattern making to enable unconstrained, multi-variable optimized pattern developments. Rather than simply calculating a pattern geometry based on exact human measurements, generative algorithms treat pattern making perfectly balance exact topological fit, dynamic biomechanical mobility, and material efficiency. In a generative workflow, the apparel engineer does not draft a pattern; instead, they define a strict set of structural constraints and performance goals. In a generative workflow, the wearer's 3D digital avatar and strict mathematical constraints regarding material properties, manufacturing limits, and biomechanical goals are fed into the system [8]. The AI algorithm then uses physical simulations to iteratively generate, evaluate, and mutate thousands of potential pattern geometries until it mathematically converges on the single most optimized design.

Conclusion

The transition from static 2D pattern drafting to dynamic, data-driven pattern generation marks a necessary paradigm shift in apparel engineering. Traditional pattern drafting, standard blocks and rule-based MTM systems are no longer sufficient to meet the complex biomechanical and topological realities of the human body. By embracing parametric frameworks and generative design algorithms, the industry can finally eliminate the topological blind spots that have historically compromised garment fit. Future research are carried out to mathematically optimize pattern pieces to align with exact 3D geometry of every individual. These modern approaches can minimize the massive textile waste associated with poor fit and high return rates.

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