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THE IMPACT OF DIGITAL 3D SCANNING AND VIRTUAL FITTING TECHNOLOGIES ON GARMENT FIT ACCURACY AND PROCESS OPTIMIZATION IN THE FASHION INDUSTRY

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ABSTRACT

This article examines the impact of digital 3D body scanning and virtual fitting technologies on garment fit accuracy and process optimization in the fashion industry. It examines the potential of 3D scanning for creating digital body models and integrating them into clothing design, as well as the role of virtual fitting rooms in improving fit accuracy, personalization, reducing returns, and optimizing production processes. The advantages and limitations of these technologies are analyzed, including issues of fabric simulation fidelity, data standardization, and the privacy of personal measurements. The findings demonstrate that 3D technologies have the potential to significantly improve the efficiency and sustainability of the fashion industry, providing new opportunities for customization and digitalization of processes.

KEYWORDS

3D body scanning, virtual fitting, garment fit accuracy, digital technologies, fashion industry, production process optimization, customization, virtual avatar, digital clothing design.

Introduction

The fashion industry is one where clothing fit is a crucial factor in quality, comfort, and customer satisfaction. Traditional methods (manual measurements, standard size charts) often fail to adequately capture the diversity of body types, proportions, posture, and movement patterns. This leads to ill-fitting clothing, high return rates, customer dissatisfaction, and overproduction. With the global growth of online retail, where customers don't have the opportunity to try on items in person, this problem is especially pressing.

virtual fitting are increasingly becoming fashionable. Try-on (VTO). These technologies make it possible to create precise digital "avatars" of customers (3D models of their bodies) and use them to conduct virtual try-ons of clothing before physical production or purchase. This approach opens up opportunities for: improving fit accuracy, reducing returns, personalization (made-to-measure, customization), streamlining production processes, and creating a more sustainable clothing supply chain.

In recent years, a significant number of studies have been published confirming the benefits and potential limitations of these technologies. For example, in the scientific paper "A Review" on 3D

Body Scanning for Garment Manufacturing » examines in detail the principles, applications, and challenges of 3D body scanning in apparel manufacturing. The authors analyze how 3D scans enable a shift away from universal standard sizes and toward a more precise, customized approach [1].

Except Moreover, the study “Development and evaluation of accurate 3D human models using scan data: a comparison with SMPL and CLO models” demonstrates possibilities combined methods: use high-resolution 3D scanning bodies + algorithms deformations skeleton For receipt anatomically precise virtual models. This is important for applications that require not just a “try-on” but correct fit, ergonomics, and adaptation to movements [2].

On the other hand, the use of virtual try-on experiences (VTO) is gaining increasing attention from a consumer experience and retail perspective. A systematic review, "Virtual Try-On Systems in Fashion Consumption: A Systematic Review” showed that VTO systems can reduce uncertainty in online shopping, increase user confidence in the fit of clothing, and help reduce returns [3].

There have also been studies using virtual 3D prototyping for specialized clothing. For example, in the work "Design and Evaluation of Mastectomy Bras Using 3D Virtual Prototyping » demonstrated how software (CLO 3D) can be used to design a post-mastectomy bra: to evaluate fit, comfort, aesthetics and ergonomic parameters without the need to create a physical trial sample [4].

Also, the development of specialized pattern libraries (patterns) taking into account the diversity of body shapes is one of the promising areas. In the study "Development of a body type optimized pattern library based on fit adjustment frameworks" describes a systematic approach to optimizing patterns for various body types based on virtual 3D models. This significantly expands the possibilities for made-to-measure and custom clothing [5].

However, despite significant progress, the technology is not without challenges. The literature notes the need for standardization of scan and data formats, consideration of posture and body proportions, correct modeling of tissue behavior, motion simulation, and integration into existing production chains [1].

Our research is therefore based on the assumption that the combination of 3D scanning and virtual fitting can significantly improve garment fit accuracy, optimize design and production processes, enhance consumer experience, and contribute to the sustainable development of the fashion industry.

3D body scanning is the process of obtaining a three-dimensional digital model of the human body with detailed anatomical information (geometry, proportions, shapes, posture, etc.). Such a model can be used for further analysis, visualization, clothing design, and other purposes [1]. In his review dedicated to 3D body scanning , the authors point out that the technology is finding application not only in the fashion industry, but also in the broader context of “human - centered applications” - anthropometry, health, ergonomics, body shape analysis, avatar creation, etc. [6]. At the same time, 3D body Scanning in the context of tailoring and fashion is seen as a way to customize , create " made - to - measure " products, improve the fit of clothing and reduce dependence on standard sizing.

Virtual try-on (VTO) is a technology that allows you to “try on” clothes on a digital 3D model (avatar) of the user before physical production or purchase. VTO can work through 3D avatars, 3D clothing models , fabric simulation, visualization of fit, silhouette, and volume, much as if a person were putting the clothing on [1]. Modern VTO systems can use a combination of 3D body scans, 3D clothing models, and software simulation to evaluate fit, drape, and shape, visualize from all angles, calculate fit, and select a size or custom parameters. According to a scientific review, VTO technologies are

gaining increasing recognition: they are seen as a significant innovation for improving the customer experience, reducing uncertainty in online shopping, and increasing the likelihood of purchase [3].
In total, 3D scanning and virtual fitting offer the following key benefits for the fashion industry:
1. Customization and precision fit: Using precise anthropometric data and a 3D model, we can create clothing that best matches the shape and proportions of a specific person, including non-standard body types.

2. Reducing the burden on traditional size charts: you can move away from the standard sizes "S, M, L …" and offer custom, more precise sizes or even clothing made to individual measurements.

3. Optimized design and production: Digital models allow garments to be designed and tried on virtually before physical sewing, reducing the number of physical samples and saving materials and time.

4. Improving the consumer experience, especially when shopping online, VTO reduces uncertainty and helps the consumer evaluate the fit and appearance of clothing on their body, which can increase purchase confidence, reduce returns, and improve satisfaction.

5. Sustainable production and customization: the ability to produce only "made to order" products, minimizing overproduction, waste, and inventory, making the fashion industry more sustainable and cost-effective.

Despite all the advantages, there are also significant limitations:
1. Accuracy and standardization issues: 3D scans do not always provide stable and reproducible measurements; differences in equipment, algorithms, body positions during scanning, etc. can lead to errors [7].

2. Difficulties in simulating fabric behavior and garment fit: virtual models can accurately convey shape and silhouette, but it can be difficult to adequately simulate drape, tension, folds, and body movement.

3. High requirements for technology, equipment and skills: the implementation of 3D scanning and VTO requires professional equipment, software, and qualified specialists, which increases costs and may be an obstacle to mass application [8].
4. Problems with compatibility, data standardization, and integration into existing production chains: it is necessary to develop uniform standards and ensure compatibility of 3D model formats, data, patterns, sizes, etc.

Table 1 - Main technologies and their capabilities/limitations

Technology / approach	Main purpose	Advantages	Limitations/Challenges
3D -body scanning	Obtaining an accurate 3D -model of the human body: shape, proportions, anthropometry	Accurate anthropometric data; a database for custom clothing; the ability to create a customer avatar ; expanded coverage of body types and personalization.	Variability in accuracy; dependence on body position; requirement for standardization; need for equipment and qualifications.
Virtual fitting (VTO) + 3D -clothing modeling	Visualization of clothing on a 3D-model, assessment of fit, silhouette, adjustment, testing before sewing or purchasing	Reduce uncertainty in online -shopping; save on trial samples; customization ; improve user experience; reduce returns.	Challenges in realistically simulating fabric, drape, and movement; the need for powerful software and computations; issues of standardization and compatibility; potential errors in fit simulation.
Digital patterns + digital design (pattern + 3D CAD)	Create patterns and design clothing directly in the digital environment; convert 3D models into 2D patterns for sewing	Accelerated development; reduced waste; ability to quickly iterate designs; adapt to individual sizes.	Requirements for specialist qualifications; the need for standardization; potential discrepancies when converting from a 3D model to a 2D pattern; difficulty in accounting for fabric dynamics and fit.

The use of 3D body scanning and virtual try-on (VTO) technologies has a significant impact on garment fit, the efficiency of design and production processes, and increased customer satisfaction. Below, we analyze the key aspects of this impact:

1. Improving fit accuracy and reducing sizing errors. 3D body scanning creates an exact digital copy of a person's outer surface, allowing it to be used for pattern calculations and virtual fittings. A classic study notes that 3D body scans + virtual " fit " (virtual Fit measurements allow one to see how clothing will fit on the body, showing the distances between the body and the clothing (for a loose fit) or the distribution of fabric tension (for a tight fit) [9]. As a result, for made-to-measure or customized clothing, it is possible to achieve a fit that more closely matches the individual anthropometric parameters of the buyer.

2. Reducing returns and errors in online purchases. One of the significant drawbacks of "heavy" online fashion is the high rate of returns due to poor fit and failure to meet expectations. Scientific reviews emphasize that the introduction of 3D scanning and VTO allows brands and retailers to recommend a size that more accurately fits the buyer's body, reducing the risk of error [10].

A study using mobile 3D scanning showed that consumers using the technology to order made-to-measure clothing reported satisfaction with the fit, confirming the effectiveness of scanning for customization [11].

3. Reducing time and material costs and accelerating collection development. Digital modeling and virtual fittings allow designers and engineers to check the fit and form of clothing even at the digital

prototype stage - before sewing a physical sample. This reduces the need for multiple trial samples, saves fabric and labor, and speeds up the development cycle [12].

Thus, especially for customized clothing or small-batch / made-to-order production, technology makes the process more streamlined and cost-effective.

4. Improving the consumer experience and personalization. A virtual try-on experience, tailored to individual body measurements, and a digital "avatar", gives the buyer confidence that the clothing will fit. This reduces the uncertainty inherent in online shopping and increases brand trust [13].

For people with non-standard measurements (atypical figures, plus-size , wide height/shoulders/hips, etc.), technology is especially important: standard size charts often provide a poor fit, and customization via 3D scanning and a virtual avatar is the solution to this problem.

5. Increased sustainability of production and reduction of excess production. Because clothing is tailored to the customer's actual measurements (made-to-measure), overproduction, inventory, and the number of returned (and often disposed of) items are reduced. This makes production more environmentally friendly and cost-effective.

Consequently, 3D body scanning and virtual fitting technologies are becoming a powerful tool for improving garment fit accuracy and streamlining design and production processes. They significantly reduce sizing errors, decrease the rate of returns, reduce costs and speed up the development cycle, and improve consumer comfort and satisfaction, especially for customized and bespoke clothing. However, their effectiveness depends on the quality of scanning, the realistic fabric simulation, and the integration of the technology into production processes.

Based on the analysis, the following recommendations can be developed for the further development and application of 3D technologies in the fashion industry:

1. Developing standards: It is important to develop industry standards for 3D scanning (formats, metrics, anthropometry) to ensure compatibility between different systems and brands.

2. Integration of fabric movement and dynamics: Further research and development should consider fabric movement behavior, drape, and tension to enable virtual fitting to provide a more realistic fit assessment.

3. Mass customization : 3D scanning makes it possible to provide made-to-measure and custom clothing even in mass production, which will increase customer satisfaction and reduce overproduction.

4. Balancing privacy and convenience: Brands and retailers should develop transparent policies for handling personal data (body scans) to alleviate consumer anxiety.

5. Training and digital literacy: With the growth of digitalization, it is necessary to improve the competencies of designers, constructors, and fashion designers in the field of 3D modeling, virtual fitting, and digital clothing design.

Thus, digital technologies (3D body scanning and virtual try-ons) are having a significant impact on the fashion industry, helping to improve garment fit, streamline design and production processes, and enhance the consumer experience. However, these technologies continue to evolve: challenges remain related to realistic fabric simulation, standardization, privacy, and adaptability to diverse body shapes. Nevertheless, with further research and implementation, 3D technologies can become the foundation for a more sustainable, personalized, and efficient fashion industry.

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