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A Review of 3D Digital Garment Simulation Strategies for Enhanced Wearables and Medical-Grade Applications ⋆

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Abstract

This paper thoroughly reviews the current state of digital simulation technology and its strategic implementation across applications, primarily focusing on advanced compression garments. Despite the significant impact of three-dimensional digital garment simulators (3DGS) on the apparel and textile industry, their usage has largely been confined to visual prototyping, visual quality check, or marketing tools. Notably, these simulators' physical or mechanical representation has been understated in the context of advanced functional manufacturing. This review delves into the potential strategic integration of virtual physical properties to augment garment functionalities, particularly within wearables and medical-grade compression fields. The initial phase of this study provides a comprehensive overview of the status of 3D garment simulation tools and their digitisation capabilities. Subsequently, a gap analysis focuses on minimising disparities between simulated and actual physical property assessments. Despite the absence of reliability and standardised testing within a virtual environment, this paper focuses on the relevant literature to gain crucial insights for apparel and textile engineers, providing a nuanced understanding of the capabilities and limitations of 3DGS mechanical representation in enhancing advanced functionalities, specifically customised for diverse end-users.

Keywords: 3D Digital garment simulator; Advanced compression garment; Digital strategy; Medical-grade compression; Simulated physical property; Virtual evaluation

1 Introduction

Over the past few years, the apparel and textile industry has transformed by incorporating digital technologies into its supply chain [1]. The conventional process involved sending physical samples to remote stakeholders, leading to delays in production lead time [2]. However, adopting 3D digital garment simulators (3DGS) has proven useful in saving lead time and improving work efficiency by facilitating communication among buyers, contractors, and sourcing agents. For

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example, Li & Fung, a leading apparel sourcing agent, reported a 48% reduction in production time through their digitised manufacturing process. It typically takes about 40 weeks for an apparel line to go through the supply chain [3]. Consequently, manufacturers have increasingly adopted digital 3D garment tools to facilitate collaboration with buyers [1].

Despite the industry's widespread adoption of digital technology, a gap exists between the accuracy of digitally designed products and physical prototypes. While a significant portion of the existing literature has primarily focused on the visual fidelity of garments, encompassing drape [4, 5], pattern optimisation [6], and a visual quality check [7], virtualised physical or mechanical representation in 3DGS features have been overlooked. This oversight may stem from the lack of standardised testing and reliability in computing physical properties. To realise the full potential of digital simulation, accurate prediction of the fabric's objective properties (i.e., strain, stress, pressure), subjective properties (i.e., drape), and garment functionality (compression) are essential. Precise simulators are pivotal in elevating advanced garments, particularly wearable or medical-grade compression garments. However, the design of such clothes presents formidable challenges, necessitating meticulous considerations encompassing fibre constituents, yarn compositions, fabric densities, garment types, and customised fit catering to distinct body dimensions. These pivotal design factors can be effectively simulated through state-of-the-art digital 3D technologies, such as 3DGS, enabling proactive modelling of functional or wearable properties ahead of physical production [8]. Therefore, this study critically reviews the possibility of strategically utilising digital technologies to aid in engineering functional compression garments. The review paper is divided into three sections:

1. Examination of 3D Digital Garment Design Simulators (3DGS) and Virtualized Physical Property Evaluation

2. Addressing the Discrepancy Between Simulated and Physical Properties for Functional Garment Design

3. Strategic Implementation of Digital Technology for Advanced Compression Garments

2 Overview of 3D Garment Simulators and Virtualized Physical Property Evaluation

Conventionally, cloth simulators utilise a physics-based mass-spring model, representing the polygonal cloth model as a grid of interconnected mass particles using springs [9]. The model incorporates three primary spring types - structural, shear, and bending - to capture the characteristics of the virtualised fabric. Initially, all springs are set to their rest state, but upon simulation start, the set of springs changes based on the input of physical property parameters, which influence the movement and configuration of the springs. Hence, digitising fabric requires inputting physical property measurements of actual fabrics.

Various 3D garment simulators are available in the industry, including CLO 3D (Clo Virtual Fashion), VStitcher (Browzwear), 3D virtual clothing (OptiTex), Modaris 3D Fit (Lectra), Vidya (Assyst-Bullmer), and Marvelous Designer systems [10]. Despite the active utilisation of 3D simulation technology, the virtual measurement capabilities of the simulators have not been fully explored in advanced functional garment manufacturing. However, there is no standardised testing method or guidance to optimise virtual fabric to match physical fabric properties, as different