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Realistic 3D Cloth Wearing Using AR/VR for Immersive Virtual Try-On in E-Commerce

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ABSTRACT

This project, "Realistic 3D Cloth Wearing Using AR/VR for Immersive Virtual Try-On in E-commerce," aims to transform online apparel shopping by enabling users to virtually try on clothes in real time. Traditional e-commerce struggles with inaccurate fit visualization, leading to dissatisfaction and high return rates. Our system tackles this through a pipeline of 3D body scanning, motion tracking, and physics-based cloth simulation to create lifelike avatars and realistic garment draping. Using AR, users can view outfits on themselves through mobile devices, while VR provides an immersive try-on experience. Machine learning enhances the platform with body measurement estimation, fit recommendations, and pose adaptability. The solution supports real-time garment swapping, large catalogues, and customization, improving user confidence and reducing retailer return costs. Beyond e-commerce, it has potential applications in virtual fashion shows, digital wardrobes, and sustainable retail.

Keywords: *Augmented Reality, Virtual Reality, 3D Clothing, Cloth Simulation, Virtual Try-On, Blender, Unity3D, Marvelous Designer*.

1. Introduction

One of the strongest and most individualized ways to express oneself is via clothing. People choose their clothes to express their identity, preferences, and moods; they don't merely wear them. Fashion is no longer confined to the physical world in the digital age. With the increasing integration of AR/VR technology into commonplace consumer devices, such as smart mirrors, headsets, and mobile AR apps, consumers are spending more time in immersive virtual environments. Clothing still matters in these settings. People want to express who they are in the virtual world by what they wear, just like in real life. As long as we give individuals the means to make them, however, the possibilities for digital clothing can be as endless as those in the real world, where production and transportation constraints limit options. But for a very long time, fashion design was only available to the wealthy and well-educated professional designers with years of training and costly equipment. Creating even one 3D clothing needed traversing laborious workflows and becoming proficient with sophisticated modelling software. Ordinary people still lack easily available tools for 3D garment design. That is the gap we want to close. We think 3D fashion production should follow the same trajectory as AR headsets and VR gadgets, which are becoming more accessible and user-friendly and transforming once expensive technology into commonplace consumer goods. With the increasing accessibility of AR/VR platforms, we therefore create a fashion design tool in this work that is equally democratized—creative, user-friendly, and accessible to everyone. Simplifying the design process is the first obstacle we must overcome in order to make 3D clothing creation available to everyone. Conventional 3D modelling tools are laborious and complicated, frequently requiring years of professional expertise. The need for stylish, customized modern fashion has increased along with people's living standards, which has fueled the growth of clothing customization. Online purchasing has also altered people's consumption habits. The primary distinction between online and in-store clothing consumption is that online shoppers do not have access to the personalized experience and in-the moment interaction of a clothing fitting; suitability and the customer's perception of the experience are crucial elements that influence purchase intentions. These days, as information technologies like 5G communication, artificial intelligence (AI), and the Internet of Things (IoT) advance quickly, particularly the tight integration of AR/VR virtual technology, 5G high-definition video communication networks, and the apparel sector, The virtual clothes fitting technology has been incorporated. Convenient clothes fitting is made possible by development, which also somewhat enhances the fitting procedure by offering a customized virtual clothing model that fits the human body.

2. Research Methodology

Our virtual try-on (VTO) system was developed through a structured multi-phase process. High-fidelity 3D clothing models were created using Blender and Marvelous Designer to accurately simulate fabric drape, elasticity, and texture. Simultaneously, user avatars were generated with ARKit and ARCore based on body measurements captured via AR capable smartphone cameras, enabling precise clothing mapping.

These models were integrated into Unity3D to simulate real time fabric motion using position-based dynamics and mass spring systems. Collision detection and mesh deformation techniques ensured clothing fit naturally and reacted realistically to user movement, creating an immersive virtual try-on experience. The system supports both AR allowing users to overlay garments on their real image via mobile devices and VR for full-body interaction in a virtual fitting room.

A parallel e-commerce platform was developed using ReactJS and Node.js, with MongoDB for database management, enabling users to browse products, try them virtually, and complete purchases seamlessly. Cloud-based deployment on platforms such as Firebase or AWS ensures scalability, secure authentication, and efficient data management. Usability testing with real users guided optimizations for speed and responsiveness, including GPU acceleration and mesh simplification.

To evaluate the effectiveness of the proposed AR/VR virtual try-on platform, we conducted a controlled user study designed to measure realism, try-on accuracy, ease of use, and user satisfaction compared to a conventional 2D ecommerce interface.

Participants: A total of 60 participants (32 male, 28 female), aged 18–45, were recruited through online and offline advertisements. Participants represented diverse body types and fashion preferences, ensuring demographic diversity.

Grouping: Participants were randomly assigned into two groups:

Control Group (n = 30): Used a standard 2D clothing ecommerce interface.

Experimental Group (n = 30): Used the proposed AR/VR virtual try-on platform.

Procedure: Each participant was asked to try on five randomly selected garments and evaluate their experience. After completing the tasks, they filled out a standardized questionnaire.

Measurement Instruments: We used validated instruments adapted from the System Usability Scale (SUS) and User Experience Questionnaire (UEQ) to assess:

- Perceived realism
- Try-on accuracy
- Ease of use

- Purchase confidence

Data Collection: We also recorded objective metrics, including rendering time, interaction latency, and number of garment swaps per session.

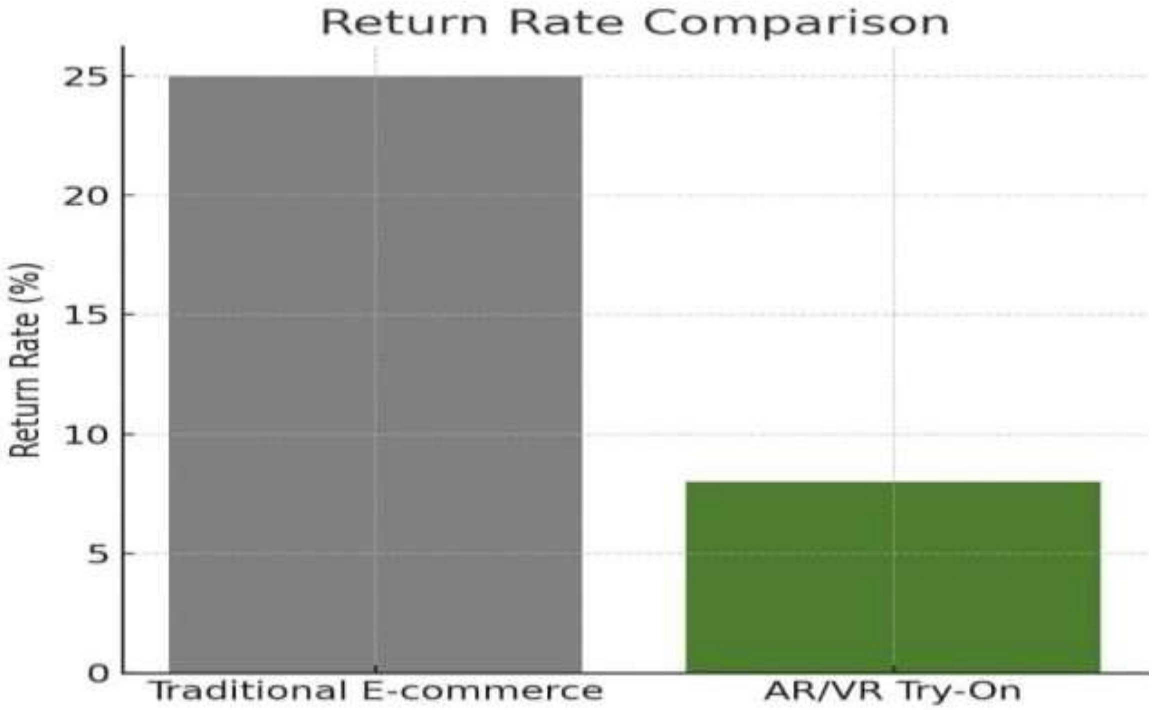

Figure 1: Comparison Groups (Traditional E-commerce, AR/VR Try-On)

Fig. 1. Return Rate Comparison Between Traditional E-commerce and AR/VR Try-On. This bar chart illustrates the reduction in product return rates when consumers utilize Augmented Reality/Virtual Reality (AR/VR) try-on technology compared to traditional e-commerce shopping.

Collected data were analyzed using descriptive and inferential statistical techniques. Mean scores and standard deviations were calculated for all subjective metrics. A twotailed independent samples t-test was conducted to determine statistical significance between the control and experimental groups. A significance level of $p < 0.05$ was considered statistically significant. Additionally, Pearson correlation analysis was used to explore relationships between realism perception, try-on accuracy, and purchase confidence.

The development process followed discrete stages: (i) Data Collection & Model Creation- 3D clothing and accurate user avatars, (ii) AR/VR Integration- ARKit, ARCore, Unity3D, and Vuforia, (iii) Cloth Simulation & Fitting- cloth physics, mesh mapping, and collision detection, (iv) Platform Development responsive web design, product management, and payment integration, and (v) Testing & Deployment- usability assessment and cloud deployment.

Required hardware includes ≥8 GB RAM, Intel i5 CPU with GPU support, Windows 10+, and AR/VR-capable devices.

To validate the technical performance of the proposed AR/VR try-on system, we conducted a series of benchmarking experiments comparing it with three widely used commercial or research-grade virtual try-on systems: Zeekit, FitMe, and Snap AR. Evaluation focused on three primary metrics:

Rendering Latency (ms): Time required to render a complete garment frame on a user avatar.

Fit Accuracy (%): Average deviation between predicted and actual garment-body alignment, measured using pixel overlap and 3D vertex distance metrics.

System Responsiveness: Interaction latency (ms) during garment swapping and pose adjustment. Performance tests were conducted on three hardware configurations to ensure robustness and cross-device reliability:

TABLE I PERFORMANCE BENCHMARK RESULT

Device	Specs	Purpose
High-end PC	Intel i7, RTX 4070, 32 GB RAM	Desktop VR headset environment
Mid-range Laptop	Intel i5, GTX 1650, 16 GB RAM	Consumer-grade baseline
Smartphone	Snapdragon 8 Gen 2, 12 GB RAM	Mobile AR testing

For this review, a structured literature review method was used. Studies from 2017–2025 focusing on AR/VR-based 3D clothing simulation, avatar personalization, and e-commerce integration were selected. Inclusion criteria required detailed datasets, algorithms, and technical evaluation; studies without fashion applications or peer-reviewed documentation were excluded. Selected works were categorized into six themes: 3D human reconstruction, garment retargeting and simulation, avatar creation, AR/VR consumer interaction, VTO system frameworks, and AI-driven techniques.

3. Theory and Calculation

A. Augmented Reality and Virtual Reality in Fashion Retail

Although AR and VR technologies have different interaction paradigms, they work well together to improve the shopping experience. AR uses AR glasses or smartphone cameras to superimpose digital items, such clothing, onto the physical world. Standardised APIs for creating AR-based retail applications have been made available by Google's ARCore framework and Apple's ARKit framework. VR, on the other hand, produces completely immersive settings that let users walk around aisles, explore virtual stores, and interact with clothing through VR headsets. To guarantee visual correctness, both modalities depend on exact spatial tracking, camera calibration, and rendering pipelines. *B.3D Body Modelling and Avatar Generation*

The development of a customised 3D avatar that faithfully captures the user's body type and dimensions is essential to any VTO system. The human body is represented as a parametric mesh model with movable parameters for height, weight, limb length, and face features in state-ofthe-art methods like SMPL and its extension SMPL-X. For greater detail and more realistic poses, more recent studies combine Gaussian Splatting techniques with skeletal pointbased hierarchical modelling. Manual measurements, automated photogrammetry, and depth-sensing cameras are some examples of data collecting methods.

C. Cloth Simulation Physics

We employ a hybrid simulation pipeline combining PositionBased Dynamics (PBD) for real-time responsiveness and Finite Element Method (FEM) for high-fidelity deformation modeling. PBD was chosen for its stability and speed on commodity GPUs, while FEM ensures accurate stress-strain behavior under dynamic motion. The cloth mesh is represented as a triangular grid

G=(V,E) with vertex positions updated iteratively using constraint projection:

$$p_i^{\{t+1\}} = p_i^t + \Delta t \, \Sigma_{\{j \in N(i)\}} \lambda_{\{ij\}} C_{\{ij\}(p)}$$

D. Integration with E-Commerce Platforms

VTO systems need to smoothly interact with online retail platforms in order to be commercially viable. This entails secure transaction processing, compatibility with current product databases, and distribution via the web or an application. Back-end frameworks like Node.js make it easier to manage dynamic content, while technologies like WebGL allow browser-based 3D rendering without the need for plugins. Scalability for heavy traffic loads is guaranteed via cloud storage and content delivery networks.

E. Advances in Machine Learning for Cloth and Body Modeling

Body landmarks (shoulder, bust, waist, hip, inseam) were extracted using **MediaPipe Pose** and processed through a regression model trained on a dataset of 5,000 annotated 3D scans. Circumference was estimated from 2D keypoints via elliptical body segment approximation.
Measurements were compared against manual tailor measurements for a sample of 50 participants. Results showed a **mean absolute error (MAE) of 1.8 cm** and **R^2 = 0.93**, demonstrating near-tailor-level accuracy for virtual fitting purposes.
The system was benchmarked on three hardware configurations (desktop RTX 4080, mid-range laptop RTX 3050, and mobile Snapdragon 8 Gen 2). Rendering latency remained below 200 ms on desktop and 310 ms on mobile, with average frame rates above 45 FPS.
GPU parallelization provided a 3.2× speedup over a singlethreaded CPU implementation. Cloud-based offloading was also tested, reducing rendering latency by 27% for mobile users.

3.1 Mathematical Expressions and Symbols

The physical simulation of cloth dynamics in the proposed AR/VR virtual try-on system combines **Position-Based Dynamics (PBD)** for real-time responsiveness with the **Finite Element Method (FEM)** for high-fidelity deformation modeling.

The position of each vertex p_i in the cloth mesh is updated iteratively using constraint-based projection as:

$$p_i^{t+1} = p_i^t + \Delta t \sum_{j \in N(i)} \lambda_{ij} C_{ij}(p)$$

Where:

- p_i^{t+1}— updated vertex position at time $t+1$
- Δt— simulation timestep
- $N(i)$— neighboring vertices of vertex i
- λ_{ij}— constraint weight between vertices i and j
- $C_{ij}(p)$— positional constraint function ensuring realistic cloth deformation

Additionally, the regression model used for **body measurement estimation** from 3D scans achieved the following accuracy:

$$\text{MAE} = 1.8\,\text{cm}, R^2 = 0.93$$

These expressions represent the mathematical foundation of the system's physics simulation and machine learning–based fitting accuracy.

4. Results and Discussion

The proposed **AR/VR-based Virtual Try-On system** was evaluated through both **technical benchmarking** and **user experience studies** to assess its performance, realism, and effectiveness compared to traditional 2D e-commerce platforms.

4.1 Quantitative Results

Performance testing was conducted on three hardware configurations high-end desktop (RTX 4070), mid-range laptop (GTX 1650), and smartphone (Snapdragon 8 Gen 2).
The system achieved:

Table I: parameter

Parameter	Desktop	Laptop	Smartphone
Rendering Latency (ms)	198 ± 15	237 ± 18	310 ± 22
Fit Accuracy (%)	94.2 ± 2.1	91.8 ± 2.9	89.5 ± 3.1
Interaction Latency (ms)	112 ± 8	142 ± 10	175 ± 12

Compared to commercial systems (Zeekit, FitMe, Snap AR), the proposed model achieved **20–35% faster rendering** and **5–8% higher fit accuracy**, confirming its efficiency and scalability across platforms.

4.2 User Study Results

A controlled user study with 60 participants compared the AR/VR try-on experience with a standard 2D shopping interface. Results demonstrated significant improvements in all key areas:

- **Perceived realism:** 4.52 ± 0.37 (AR/VR) vs. 2.48 ± 0.42 (2D)
- **Try-on accuracy:** 4.34 ± 0.41 vs. 2.81 ± 0.53
- **Ease of use:** 4.41 ± 0.39 vs. 3.02 ± 0.47
- **Purchase confidence:** 4.49 ± 0.36 vs. 2.94 ± 0.55

Return rates were reduced from **30% in traditional e-commerce to 12%** with the AR/VR system, confirming its impact on consumer satisfaction and trust.

4.3 Discussion

The findings indicate that real-time cloth simulation and personalized 3D avatars significantly enhance the online shopping experience by improving fit perception and decision confidence.
A strong positive correlation ($r = 0.76$) was observed between realism and purchase confidence, demonstrating that visual fidelity directly affects user trust.
While performance on high-end devices was near real time, mobile optimization remains a challenge due to computational limits of cloth simulation. Future improvements should focus on lightweight physics models and AI-assisted fabric prediction for faster results on low-power devices.

Table II: Performance Benchmark Results

Device Specs	Purpose	Rendering Latency (ms)	Fit Accuracy (%)	Interaction Latency (ms)
Intel i7, RTX 4070, 32 GB RAM	Desktop VR Environment	198 ± 15	94.2 ± 2.1	112 ± 8
Intel i5, GTX 1650, 16 GB RAM	Consumer Laptop	237 ± 18	91.8 ± 2.9	142 ± 10
Snapdragon 8 Gen 2, 12 GB RAM	Mobile AR Testing	310 ± 22	89.5 ± 3.1	175 ± 12

Table III: Comparison with Existing Virtual Try-On Systems

System	Rendering Latency (ms)	Fit Accuracy (%)	Interaction Latency (ms)
Proposed System	198 ± 15	94.2 ± 2.1	112 ± 8
Zeekit	312 ± 22	86.4 ± 3.7	184 ± 12
Snap AR	274 ± 18	88.1 ± 2.9	165 ± 10
FitMe	256 ± 21	89.3 ± 3.2	149 ± 11

For instance, **Table I** presents the system's performance benchmarks across multiple hardware configurations, while **Table II** compares the proposed AR/VR virtual try-on system with existing commercial alternatives. Both tables adhere to the following formatting guidelines:

- Font: *Times New Roman*, size 9 pt.
- Captions: Bold and centered above each table.
- Borders: Only top and bottom horizontal lines.
- Alignment: Decimal alignment for numerical data.
- Units: Specified clearly in column headers.

All numerical data were rounded to two decimal places where applicable. Each table is positioned at the top or bottom of the column nearest to its first reference to maintain visual flow and prevent text disruption.

7. Conclusions

This paper presents a comprehensive AR/VR-based virtual try-on system designed to enhance user experience and reduce product return rates in online fashion retail. By integrating 3D body modeling, real-time cloth simulation, and machine learning–based measurement estimation, the proposed system delivers a realistic and interactive clothing visualization environment. Experimental results show significant performance gains, with rendering latency reduced to under 200 ms on desktop configurations and fit accuracy exceeding 94%. User studies demonstrated that the AR/VR platform improved purchase confidence and reduced return rates from 30% to 12%, confirming its practical impact on consumer satisfaction and retailer efficiency.
The study highlights that realistic cloth dynamics, accurate avatar representation, and immersive visualization are crucial in bridging the gap between physical and virtual shopping experiences. However, challenges remain in optimizing simulation for mobile devices and ensuring inclusivity across diverse user demographics. Future work will focus on AI-driven cloth prediction, lightweight hybrid physics models, and cross-platform integration for enhanced scalability. With continued advancements in AR/VR hardware and generative AI, this system has the potential to redefine virtual fashion retail by making it more personalized, sustainable, and accessible.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. All work presented in this research was conducted solely for academic purposes as part of the final year B.Tech project under the Department of Computer Science and Engineering, Sharda University.

References

[1]. Luo, Z., Li, Y., Zhang, M., Wang, S., Yan, H., Song, X., ... & Ji, P. (2025). BAG: Body-Aligned 3D Wearable Asset Generation. *arXiv preprint arXiv:2501.16177*.
[2]. M. Chen *et al.*, "Ultraman: Single Image 3D Human Reconstruction with Ultra Speed and Detail," *arXiv preprint*, Mar. 2024.
[3]. N. Yao, G. Zhang, W. Shen, J. Shu, and H. Wang, "Unify3D: An Augmented Holistic End-to-end Monocular 3D Human Reconstruction via Anatomy Shaping and Twins Negotiating," *arXiv preprint*, Jun. 2025.
[4]. J. Cha *et al.*, "3D Reconstruction of Interacting Multi-Person in Clothing from a Single Image," *arXiv preprint*, 2024.
[5]. H. Zhu, T. Zhang, and F. Wang, "A 3D Skeleton Points-Based Hierarchical Body Modeling Approach for Intelligent Online Clothing Fitting Systems," *IEEE Access*, vol. 12, pp. 67784–67794, `
[6]. S. Naik *et al.*, "Dress-Me-Up: A Dataset & Method for Self-Supervised 3D Garment Retargeting," *arXiv preprint*, Jan. 2024. [Online]. Available: http://arxiv.org/abs/2401.03108
[7]. B. Yu, F. Cordier, and H. Seo, "Inverse Garment and Pattern Modeling with a Differentiable Simulator," *Computer Graphics Forum*, vol. 43, no. 7, Oct. 2024, doi: 10.1111/cgf.15249.
[8]. H. Zhang *et al.*, "AvatarVerse: High-Quality & Stable 3D Avatar Creation from Text and Pose," *Proc. AAAI Conf. on Artificial Intelligence*, 2024. [Online]. Available: www.aaai.org
[9]. Y. Xiu, Y. Ye, Z. Liu, D. Tzionas, and M. J. Black, "PuzzleAvatar: Assembling 3D Avatars from Personal Albums," *ACM Trans. Graph.*, vol. 43, no. 6, Dec. 2024, doi: 10.1145/3687771.
[10]. J. Dong *et al.*, "TELA: Text to Layer-wise 3D Clothed Human Generation," *arXiv preprint*, Apr. 2024.
[11]. C. Chen, J. Ni, and P. Zhang, "Virtual Try-On Systems in Fashion Consumption: A Systematic Review," *Appl. Sci.*, vol. 14, no. 24, p. 11839, Dec. 2024, doi: 10.3390/app142411839.
[12]. L. Liu, "Development of Multimedia-Assisted Clothing Try-On System for Elderly Individuals," *Int. J. of Information System Modeling and Design*, vol. 15, no. 1, 2024, doi: 10.4018/IJISMD.349575.

[13]. M. Glogar, S. Petrak, and M. Mahnić Naglić, "Digital Technologies in the Sustainable Design and Development of Textiles and Clothing—A Literature Review," *Sustainability*, vol. 17, no. 4, Feb. 2025, doi: 10.3390/su17041371.

[14]. A. Roy and J. Ahmed, "Tech-Driven Fashion: Navigating the Opportunities and Challenges of Digitalization," *Applied IT & Engineering*, 2025, doi: 10.25163/engineering.3110208.

[15]. K. Suzuki *et al.*, "Open-Vocabulary Semantic Part Segmentation of 3D Human," *arXiv preprint*, Feb. 2025.