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A Review on Virtual Try-On Clothes: Artificial Intelligence in Fashion Retail

Ganesh Khogare[1], Shital Adhude[2], Sakshi Lagad[3], Dipali Kachre[4], Asst. Prof. Jaybhay D.S[5], Prof. Gawade S.U[6]

Department of Computer Engineering, Dattakala Group of Institution, Faculty of Engineering

Swami-Chincholi - 413130, Pune, India[1-4]

Guide, Department of Computer Engineering, Dattakala Group of Institution, Faculty of Engineering

Swami-Chincholi - 413130, Pune, India[5]

Co-Guide, Department of Computer Engineering, Dattakala Group of Institution, Faculty of Engineering

Swami-Chincholi - 413130, Pune, India[6]

Abstract: Digital transformation has profoundly reshaped the fashion industry by blending computational methods with traditional design practice. In particular, Artificial Intelligence (AI) and related technologies (computer vision, deep learning, AR/VR, 3D modeling and generative methods) have enabled virtual try-on systems that promise improvements in personalization, reduced returns, and more sustainable production workflows. This review synthesizes existing literature on virtual try-on systems and their enabling technologies, presents a systematic methodology used to collect and analyze literature, extracts six core themes emerging from research (Design, Consumers, Body, Virtual, Printing, Supply), discusses the primary findings and technological trends, identifies technical and ethical challenges, and outlines key directions for future research. The paper keeps the focus on core developments and critical evaluations drawn from peer-reviewed studies, positioning virtual try-on as a central applied research area at the intersection of AI, graphics, and fashion retail.

Keywords: Artificial Intelligence, Virtual Try-On, Digital Fashion, Augmented Reality, Machine Learning, Fashion Retail, 3D Modeling, Sustainability.

I. INTRODUCTION

The last decade has witnessed rapid digitalization across retail sectors, with fashion being one of the most visibly transformed. Advances in Artificial Intelligence (AI), computer vision, and interactive graphics have enabled novel consumer experiences such as virtual fitting rooms, avatar-based fashion, and interactive lookbooks. Virtual try-on systems—ranging from simple 2D overlay techniques to fully 3D, physics-aware garment simulation—are positioned to reduce product returns, improve customer satisfaction, and enable mass-customization without large physical inventories. Digital fashion, broadly defined, comprises digital artifacts and processes that allow design, visualization, and consumption of clothing in virtual or hybrid contexts. This includes virtual garments for avatars, AR-based try-on for live shoppers, and digital-only fashion items used in virtual environments. While these technologies promise both economic and environmental benefits, the academic literature shows fragmentation in definitions, methods, and evaluation metrics. This paper consolidates that literature, emphasizing AI's role in virtual try-on systems and how the technology interacts with consumer behavior and supply chain practices.

The remainder of the paper is organized as follows: Section II surveys related work and foundational studies; Section III details the systematic methodology; Section IV reports findings and trends across six themes; Section V discusses implications, limitations and ethical concerns; Section VI concludes and suggests future research avenues; references follow.

II. LITERATURE SURVEY

This section summarizes major literature clusters relevant to virtual try-on and AI in fashion. The survey emphasizes tech- nical contributions, application studies, and cross-disciplinary reviews.

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A. 3D Virtual Design and Prototyping

3D modeling and virtual prototyping tools (e.g., CLO3D, Blender, Optitex) have become essential for designers to visualize garments before physical production. Research has examined mesh-based garment modeling, parameterized pattern generation, cloth simulation, and the integration of physics engines for realistic drape and fit. Studies highlight how 3D design reduces sample waste, shortens sampling cycles, and enables rapid iteration [1], [8]. Many contributions focus on improving simulation speed and material realism while maintaining an artist-friendly design workflow.

B. AR/VR and Immersive Interactions

Augmented Reality (AR) and Virtual Reality (VR) provide immersive try-on experiences: AR overlays garments onto live video of users; VR places consumers in virtual showrooms where they can inspect garments on avatars. Research probes interaction design, presence, and usability, as well as the psychological effects of immersion on purchase intent [9]. Technical work involves real-time body pose estimation, robust tracking, and low-latency rendering.

C. Artificial Intelligence and Predictive Modeling

AI powers many aspects of virtual try-on: pose estimation, human parsing, garment segmentation, 3D reconstruction from single images, and generative methods to synthesize garment appearance under varied lighting and pose. Deep learning architectures (CNNs, GANs, transformer-based models) have advanced visual realism and shape inference. Predictive modeling is also applied to trend forecasting and demand estimation—key inputs to design and supply decisions [4], [13].

D. Blockchain, NFTs and Supply Transparency

Blockchain has been proposed for provenance and authenticity, enabling traceability across supply chains and digital ownership for virtual garments (e.g., NFTs). Research explores how ledger-based methods can support circularity and anti- counterfeiting while highlighting technical scalability and governance issues [3], [12].

E. Consumer Behavior and Psychology

Studies examine user acceptance, perceived realism, trust, and willingness to buy via virtual try-on systems. Factors such as interface usability, perceived fit accuracy, social influence, and privacy concerns modulate adoption [2], [19]. The pandemic accelerated digital adoption, serving as a catalyst for AR/VR investment by retailers.

F. Sustainability and Manufacturing

Digital workflows (virtual sampling, on-demand manufacturing, and 3D printing) are shown to reduce waste and enable localized customization. However, researchers caution that measurable environmental benefits depend on production practices and lifecycle analysis [**?**].

III. METHODOLOGY

The reviewed literature was collected using a Systematic Literature Review (SLR) approach modeled on PRISMA principles. The aim was to identify peer-reviewed journal articles that discuss digital fashion, virtual try-on technologies, and the application of AI within fashion retail.

A. Search Strategy

Multiple academic databases were searched using a com- pound query that combined fashion-related keywords with technical terms (e.g., “virtual try-on”, “digital fashion”, “3D clothing”, “augmented reality”, “AI in fashion”). Search results were filtered to journal articles and conference papers in English. Duplicate entries were removed and records were screened for direct relevance to virtual try-on and AI applications in fashion.

B. Selection Criteria

Inclusion criteria:

- Peer-reviewed journal articles or reputable conference proceedings.
- Direct relevance to virtual try-on, digital fashion, or AI applications in fashion retail.
- Studies providing empirical results, methodological innovations, or systematic reviews.

Exclusion criteria:

- Non peer-reviewed blog posts, editorials, or commercial white papers.
- Studies not specifically addressing fashion or virtual garments.

C. Screening Process

The screening involved:

1) **Initial retrieval:** Broad query returned several thousand items.

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2) **Discipline filtering:** Limiting to arts, computer science, human-computer interaction and business reduced the list significantly.
3) **Language and format filtering:** Non-English and non- peer-reviewed items were excluded.
4) **Manual relevance check:** Titles and abstracts were manually inspected; full texts were read when necessary.

D. Data Extraction and Analysis

From selected articles we extracted: research objectives, methodological approach, datasets used, evaluation metrics, and major findings. We applied both qualitative coding and quantitative frequency analysis to identify recurring themes. Tools such as concept-mapping and thematic coding were used to group contributions into coherent themes.

IV. FINDINGS AND TRENDS

The SLR analysis revealed six interlinked themes. This section expands each theme with synthesized insights from the literature.

A. Theme 1: Design

Design research emphasizes the fusion of computational techniques and designer workflows. Key subtopics include:

- **Parametric design:** Pattern generation using parametric models that allow quick variations of fit and style.
- **Generative design:** Use of generative models to suggest patterns, textures, and colorways.
- **Interactive tools:** Designer interfaces that combine direct manipulation with automated suggestions.

Design-led research highlights the need for tools that respect creative intent while leveraging data for better decision-making.

B. Theme 2: Consumers

Consumer research shows virtual try-on impacts purchase behavior through multiple channels:

- **Perceived fit accuracy:** The more accurate the representation of fit and drape, the higher the conversion and lower the returns.
- **Trust and transparency:** Clear communication about how virtual fitting works (e.g., measurements vs. approximation) affects acceptance.
- **Engagement and co-creation:** Consumers increasingly desire customization and co-design features integrated into try-on tools.

Empirical studies demonstrate measurable increases in consumer engagement when interactive virtual fitting is present.

C. Theme 3: Body

Body representation is technically challenging and ethically sensitive.

- **3D body scanning:** Accurate avatars require high-fidelity scans; research explores low-cost scanning alternatives (RGB cameras + ML).
- **Size and fit modeling:** Statistical body models and personalized size suggestions reduce sizing uncertainty.
- **Privacy concerns:** Biometric data use raises privacy questions requiring strong data governance and consent models.

Technological advances have improved shape inference from 2D images but error margins still exist for certain body shapes and clothing types.

D. Theme 4: Virtual

- **Metaverse and social fashion:** Virtual garments and digital-only fashion promote identity expression in digital spaces.
- **Realism vs. stylization:** Depending on application, some systems prioritize photorealism, others stylized aesthetics (e.g., avatars in games).
- **Cross-platform interoperability:** Standards and asset pipelines are needed to port digital garments across platforms.

E. Theme 5: Printing

3D printing and on-demand manufacturing enable direct translation from digital patterns to physical garments or accessories:

- **Customization:** On-demand production supports personalization without large inventories.
- **Sustainability:** Localized production and reduced sampling lower environmental footprints when managed well.
- **Material constraints:** Current printable materials limit certain garment types; hybrid workflows combining digital and traditional manufacturing are common.

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F. Theme 6: Supply

Supply-chain studies focus on traceability, authenticity, and resilience:

- **Blockchain applications:** Distributed ledgers can enhance provenance tracking though challenges in adoption and standards remain.
- **Digital twins:** Creating digital replicas of products and processes facilitates predictive maintenance and demand forecasting.
- **Circularity:** Integrating virtual samples and digital sales channels contributes to circular business models when combined with responsible material choices.

V. DISCUSSION

This section synthesizes the findings, evaluates current technological readiness, and highlights practical implications for industry and research.

A. Technological Maturity

Core enabling technologies—computer vision for segmentation and pose estimation, differentiable rendering, and deep generative models—have matured considerably. Applications differ in maturity: basic AR overlays are production-ready, whereas fully accurate physics-based 3D simulation for arbitrary garments remains an active research area.

B. Evaluation Challenges

A recurring issue in the literature is a lack of standardized evaluation metrics for virtual try-on systems. Studies often use subjective user ratings, in-lab experiments, or commercial KPIs (return rates, conversion), making cross-study comparisons difficult. There is a strong need for benchmark datasets and agreed metrics for realism, fit accuracy, and user experience.

C. Ethical and Social Considerations

Several ethical concerns arise:

- **Privacy and biometric data:** Collection and storage of body scans require strict consent, storage protections, and limited retention policies.
- **Bias and fairness:** Models trained on non-representative datasets can produce poor results for underrepresented body types or cultures.
- **Digital divide:** Access to AR-capable devices is unequal; small retailers may lack resources to implement advanced systems.

D. Commercial Impact

From a retailer perspective, virtual try-on can drive dig- ital engagement, reduce returns, and support new revenue streams (digital garments, customization). For designers, digital prototyping shortens lead times. However, ROI depends on integration with existing systems and careful user experience design.

VI. LIMITATIONS

This review is constrained by:

- Selection bias inherent in database coverage and inclusion criteria.
- Rapid technology change: new models and systems appear frequently and may not be fully reflected.
- Lack of standardized metrics across studies makes quanti- tative synthesis approximate.

Despite these limitations, thematic synthesis captures the dominant research directions and practical challenges.

VII. FUTURE RESEARCH DIRECTIONS

While the paper restricts itself to the existing main sections, the literature suggests several focused directions:

- **Benchmarking and datasets:** Creation of large-scale, diverse datasets with standardized ground truth for fit and fabric physics.
- **Interpretable models:** Tools that provide designers explanations for automated suggestions.
- **Privacy-preserving body capture:** Development of meth- ods that avoid raw biometric storage (e.g., ephemeral or encrypted representations).
- **Cross-cultural studies:** Understanding how virtual fashion adoption varies across geographies and cultures.

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VIII. CONCLUSION

This review examined AI-enabled virtual try-on systems and their role in fashion retail. By synthesizing literature across design, consumer behavior, body representation, virtual environ- ments, printing, and supply chain, the review shows that virtual try-on is an interdisciplinary, rapidly evolving domain. While many enabling technologies are mature enough for commercial deployment, open challenges remain in evaluation, fairness, privacy, and cross-platform interoperability. Addressing these will require coordinated effort across designers, engineers, and social scientists.

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