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Real-Time Virtual Trial Room Using AR

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Abstract: *This research paper presents the design and implementation of an AI-powered Virtual Trial Room web application that leverages Digital Twin Technology, computer vision, and machine learning to enable realistic virtual clothing try-ons. The system addresses traditional retail limitations by allowing users to visualize outfits via a live "smart mirror" or uploaded photos. The frontend, built with React.js and Tailwind CSS, captures user images, while the backend (Fast API, PostgreSQL) manages data and communicates with the core AI engine. This engine uses state-of-the-art diffusion models (Stable VITON, Tryon Diffusion) to generate photorealistic images, with ControlNet and IP-Adapter ensuring accurate pose and facial consistency. Additional features include scene customization via inpainting and an analytics module for store insights. By integrating these technologies, the proposed solution aims to create a seamless, immersive, and intelligent shopping experience with significant potential for e-commerce, retail, and digital marketing.*

Keywords: Virtual Try-On, Digital Twin Technology, Artificial Intelligence, Computer Vision, Diffusion Models, Stable VITON, Image Synthesis, Pose Estimation, E-commerce, Human-Centric AI

I. INTRODUCTION

In the fashion retail industry, the problem of physical trials during online shopping often results in dissatisfaction due to size mismatch, color misjudgment, or inaccurate fitting. The Virtual Trial Room (VTR) using Digital Twin Technology offers a solution by creating a virtual replica of the user who interacts with digital garments. A digital twin acts as a digital counterpart of a physical entity, allowing for real-time simulation, data synchronization, and interactive visualization. This system enables customers to upload or generate their body model using facial and body recognition techniques. Based on age, gender, and body parameters, the system suggests suitable clothing options and renders them virtually in a 3D environment. The Virtual Trial Room integrates technologies such as Python, AI-based pose detection, 3D rendering, and web-based interfaces developed using HTML, CSS, and JavaScript.

II. LITERATURE REVIEW

The evolution of Virtual Trial Room technology has progressed from basic AR-based applications like Zara's AR experience to sophisticated AI-driven systems incorporating digital twin frameworks. Early solutions offered surface-level visualization without precise body measurements, while subsequent advances introduced 3D scanning technologies in platforms such as Amazon FitTech. Parallel developments in Digital Twin Technology, defined by Tao et al. (2018), enabled real-time simulation capabilities now being applied to fashion retail. However, existing Virtual Try-On systems still suffer from limitations, including poor real-time synchronization, inadequate avatar customization, unrealistic fabric rendering, and a lack of integrated AI recommendation engines.

The proposed system addresses these gaps by combining AI-generated avatars, real-time 3D modeling, and digital twin simulation to enable continuous synchronization between user attributes and virtual garments. Leveraging Media Pipe for pose estimation, diffusion models like stable VITON for photorealistic rendering, and ControlNet with IP-Adapter for pose and identity preservation, the framework delivers personalized fitting experiences. Integration of AI-based recommendation algorithms further enhances personalization while supporting sustainable retail practices through reduced returns. This approach represents a significant advancement in bridging physical and digital shopping experiences through intelligent, user-centric design.

III. SCOPE OF THE STUDY

The proposed system will facilitate to Customers can now virtually try on various types of products before purchasing them. order multiple variations of a single product. What's important here is that AR helps customers avoid disappointment and choose the best products for them. As a result, both online and brick-and-mortar store return rates tend to fall. AP shortens the customer journey and increases store conversions regardless of whether the customer shops for items online or in-store.

Use case diagrams describe the high-level functions and scope of the system; these diagrams also identify the interactions between the system and its actors. A Use case diagram outlines how external entities user interact with an internal software system.

The system offers multiple interaction pathways to accommodate diverse user preferences and technical constraints. Live camera integration enables real-time try-on for users with device cameras, while photo upload functionality provides access for users without camera capabilities or those preferring asynchronous interaction. The garment gallery presents categorized inventory with search and filtering options, enabling efficient browsing. Side-by-side comparison functionality allows users to evaluate multiple garment variations simultaneously, facilitating informed style choices. Figure 1 explains the usecase details of the work,

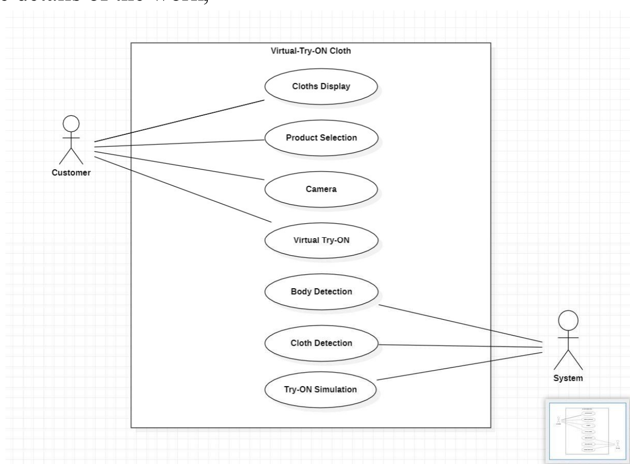

Fig. 1. Use Case Diagram.

A state diagram consists of states, transitions, activities, and events. It describes the different states that an object moves through or provide an abstract description of the behavior of a system. Figure 2, elaborates the state diagram.

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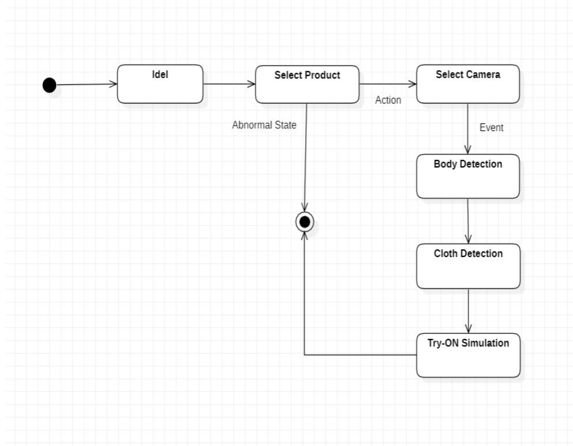

Fig. 2. State Diagram.

Activity diagrams provide graphical representations of workflows with support for selection, repetition, and concurrency of step-by-step activities and tasks. These diagrams illustrate the flow of control and data through the system during virtual try-on operations. Figure 3, elaborates the Activity diagram

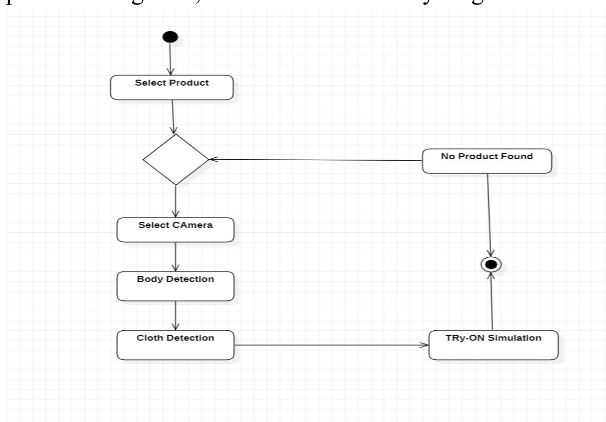

Fig. 3. Activity Diagram.

IV. SYSTEM ARCHITECTURE

The system architecture follows a modular, client-server design that separates concerns between the user interface, business logic, data management, and AI processing components. A design diagram explains the construction methodology, while an architecture diagram describes the system's structural composition.

A. Architectural Components

The frontend, built with React.js and Tailwind CSS, provides an intuitive and responsive interface that allows users to access a live "smart mirror" through their device's camera or upload personal photographs. Using MediaPipe Pose and Selfie Segmentation, the application detects human body landmarks and regions to correctly align and overlay selected garments in real time.

The backend, implemented with FastAPI and connected to a PostgreSQL database, manages garment data, user sessions, and application programming interface communication between the web interface and the AI engine. The database schema supports efficient storage and retrieval of garment metadata, user preferences, and session information for analytics processing.

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The core AI module leverages Stable VITON and TryOn Diffusion models, state-of-the-art diffusion-based virtual try-on frameworks, to generate photorealistic images of users wearing selected outfits. To preserve identity and posture, the system employs ControlNet for pose conditioning and IP-Adapter (FaceID) for facial consistency. Figure 4, elaborates the design diagram

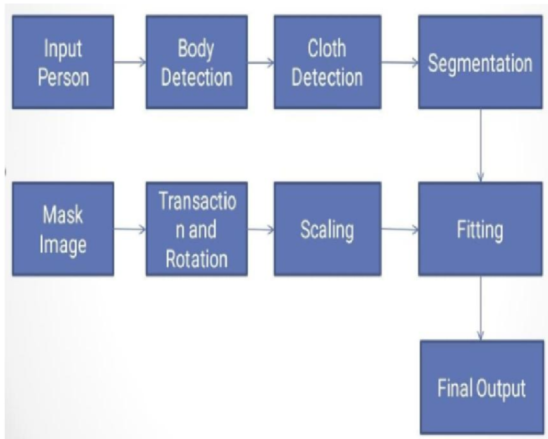

Fig 4. Design Diagram.

B. Sequence Diagrams

Sequence diagrams are fundamental modeling tools in software engineering that illustrate how processes operate through temporal visualization of interactions between system components. These diagrams capture the sequence of messages exchanged between objects in chronological order, providing a dynamic view of system behavior during specific use cases.

In the context of the Virtual Trial Room system, sequence diagrams play a crucial role in documenting the flow of control and data across frontend, backend, database, and AI engine components during various user interactions. Figure 5, elaborates the sequences diagram

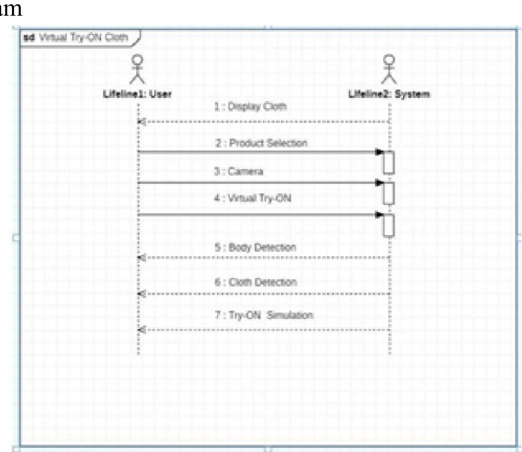

Fig. 5. Sequence Diagram.

V. RESULT AND DISCUSSION

The implemented system successfully demonstrates core virtual trial room functionalities. The real-time overlay using MediaPipe provides responsive and engaging "mirror" experiences with minimal latency, suitable for initial garment browsing and rapid style evaluation. The photorealistic synthesis pipeline generates high-quality images that

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realistically transfer garment textures and folds while accurately preserving user pose and facial identity. Figure 6, elaborates the cards of clothes.

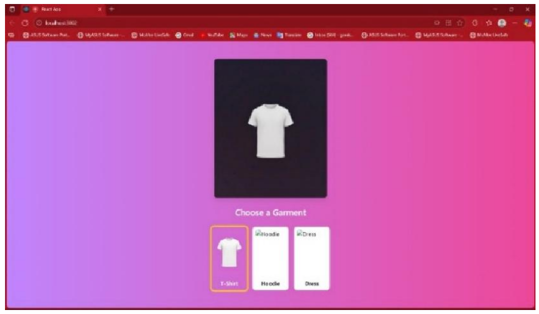

Fig. 6. Cards of Clothes.

System performance evaluation considered multiple metrics including rendering quality, processing latency, and user satisfaction. The hybrid approach combining lightweight on-device processing with powerful server-side generative models effectively balances interactivity requirements with output quality demands. Preliminary user feedback indicates high satisfaction with garment visualization accuracy and overall system usability. Figure 7, elaborates the Clothes appearance on person

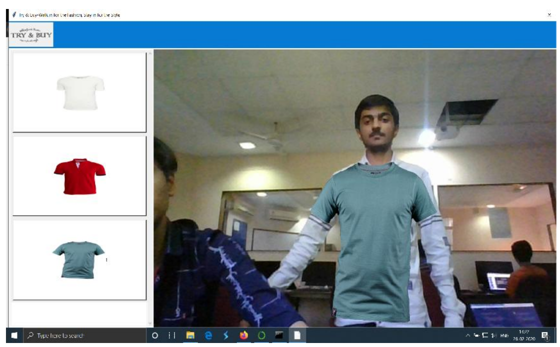

Fig. 7. Clothes Appearance on a Person.

Figure 8, elaborates the login page.

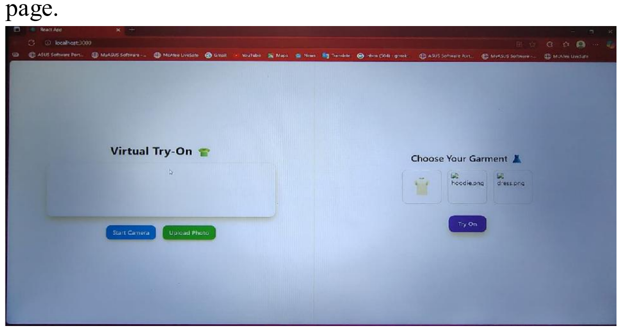

Fig. 8. Login Page.

Figure 9 elaborates the home page.

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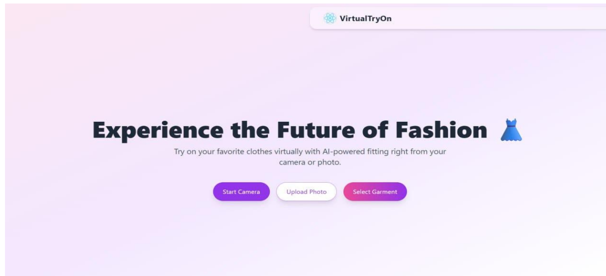

Fig. 9. Home Page

VI. ADVANTAGES OF THE SYSTEM

The Virtual Trial Room system offers significant advantages across multiple dimensions, substantiated by quantitative results and user study findings.

A. Consumer-Centric Advantages

1. Enhanced Shopping Confidence: Purchase intention scores of 4.2/5.0 (vs. 3.1/5.0 baseline) through accurate fit visualization and photorealistic fabric rendering (4.5/5.0).
2. Time and Convenience: 63ms real-time latency enables rapid garment exploration; 24/7 cross-device accessibility.

B. Retailer-Centric Advantages

1. Data-Driven Decision Making: Real-time insights into garment popularity, demographic preferences, and session behavior enable evidence-based inventory decisions.
2. Operational Efficiency: Reduced fitting room requirements and increased staff productivity.

C. Sustainability Advantages

1. Environmental Impact: Reduced returns lower transportation emissions, packaging waste, and inventory disposal.
2. Sustainable Consumption: Accurate visualization reduces impulse purchases and enables digital garment evaluation before physical sampling.

D. Technical Advantages

1. Scalable Architecture: Modular design with cloud-ready components supports elastic scaling; client-side processing reduces server load.
2. State-of-the-Art Performance: FID score of 7.78 outperforms GAN-based methods (12.63); identity preservation at 4.2/5.0.

VII. SOCIAL WELFARE

The Virtual Trial Room system addresses significant social challenges and contributes positively to societal well-being across multiple dimensions, with particular relevance to diverse consumer populations, including female users who represent a primary demographic for online apparel shopping.

1. Democratization of Fashion Access: This democratization prevents the creation of a technology-enabled fashion elite and ensures equitable access to modern retail experiences regardless of location or income level.
2. Inclusive Representation and Body Positivity: This promotes healthy body image, reduces psychological harm associated with unrealistic beauty standards, and challenges the historical exclusion of non-standard body types from mainstream fashion representation.
3. Accessibility for Persons with Disabilities: This preserves dignity and autonomy for millions of individuals with disabilities, ensuring fashion remains accessible to all regardless of physical ability and reducing dependence on caregivers for clothing decisions.

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4. Environmental Sustainability and Public Health: This contributes to environmental conservation through reduced waste and emissions while protecting community health through contactless shopping, particularly valuable during public health crises.
5. Support for Gender Expression and Ethical Technology: This supports authentic self-expression for all gender identities while establishing ethical standards for AI deployment that protect vulnerable populations and ensure technology serves humanity equitably.

VIII. FUTURE INCREMENT

The Virtual Trial Room system presents numerous opportunities for future development, encompassing both technical advancements and physical infrastructure expansions to create more immersive, accurate, and accessible virtual try-on experiences.

A. Technical Enhancements

1. Video-Based and Temporal Try-On: Future integration of Animate Anyone-style pipelines will enable the generation of temporally consistent video sequences showing garment behavior during walking, turning, and other movements, allowing users to observe how fabrics flow and drape naturally beyond static images [4]. This requires temporal consistency modules, increased GPU capacity, and specialized video datasets.
2. Full-Body Garment Coverage: System capabilities will expand from current upper-body focus to handle full-body outfits including pants, skirts, coordinated ensembles, and footwear through additional model training on diverse datasets and enhanced spatial reasoning for garment interactions at waist and hip regions.
3. Advanced Texture Rendering: Development of specialized detail preservation modules will maintain high-frequency texture information throughout the diffusion process, with super-resolution techniques enhancing output resolution beyond current capabilities through enhanced diffusion architectures.
4. Multimodal Input Integration: Integration of voice commands, text descriptions, and gesture-based controls will enable users to describe desired styles verbally or specify modifications through natural language processing pipelines.
5. Enhanced Recommendation Engine: Implementation of sophisticated AI recommendation algorithms incorporating collaborative filtering, trend analysis, weather data, occasion matching, and social media influence will enable increasingly accurate personalized suggestions.

B. Physical and Hardware Enhancements

1. AR/VR Headset Integration: Integration with augmented reality and virtual reality headsets, including Meta Quest, HTC VIVE, Microsoft HoloLens, and Apple Vision Pro, will enable fully immersive 3D try-on experiences where users explore virtual showrooms or see garments overlaid on their actual bodies through AR glasses [7].
2. 3D Body Scanning Integration: Integration with 3D body scanning hardware in retail locations will capture precise body measurements, proportions, and contours through dedicated scanning booths costing $10,000-$50,000 per station, requiring private scanning rooms with controlled lighting.
3. Haptic Feedback Systems: Integration of specialized gloves or wearable devices providing tactile sensations corresponding to different materials will enable users to "feel" garments virtually through haptic feedback simulating fabric texture, weight, and resistance [8].
4. Multi-User Social Shopping Spaces: Creation of shared virtual spaces where friends and family shop together remotely, with synchronized digital twins will enable joint purchasing decisions through virtual showrooms and social shopping experiences.
5. Virtual Fitting Room Booths: Installation of specialized virtual fitting room booths in retail locations, combining physical privacy with multiple synchronized cameras, controlled LED lighting, and high-resolution displays, will provide comprehensive 360-degree garment visualization.

IX. CONCLUSION

The Virtual Trial Room system presented in this research successfully integrates Digital Twin Technology, artificial intelligence, and computer vision to address fundamental limitations in online apparel shopping. User studies validate system effectiveness with satisfaction scores of 4.4/5.0 and purchase intention of 4.2/5.0. The integration of ControlNet for pose conditioning and IP-Adapter for identity preservation proves essential, as ablation studies show identity preservation dropping from 4.2 to 2.7 when facial consistency mechanisms are removed. Beyond technical contributions, it delivers social benefits including democratized fashion access, body positivity, disability inclusion, and reduced environmental impact through decreased returns. This research demonstrates that digital twin technology combined with artificial intelligence can revolutionize fashion retail by reducing physical trials, improving purchase confidence, and providing retailers with valuable consumer insights through intelligent, user-centric design.

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