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Web AR Virtual Try-On & Learning Platform

Amita Chandekar, Amey Dawkhar, Nandini Panchal, Sanket Ghatte, Rashmi Tuptewar
Department of Computer Science Engineering MIT ADT UniversitySS
Pune 412201, India

Abstract
The accelerating shift towards digital platforms for commerce and education has exposed significant limitations in user experience and engagement. Within e-commerce, the inability of customers to physically interact with products fosters purchase uncertainty, leading to consumer dissatisfaction and elevated rates of product returns. Concurrently, in the domain of online education, learners often struggle with engagement and the visualization of abstract concepts, which compromises the efficacy of knowledge retention. Augmented Reality (AR) presents a compelling solution to these challenges by delivering immersive and interactive experiences in real time. However, the widespread adoption of AR has been historically impeded by the requirement for users to download standalone mobile applications or utilize specialized hardware, creating substantial barriers to accessibility and scalability. This paper introduces the design and implementation of a Web AR Virtual Try-On & Learning Platform, a unified system that leverages browser-native AR technologies to deliver these immersive experiences directly, obviating the need for any installations. The platform is composed of two primary modules: a Virtual Try-On (VTO) system for e-commerce and an Interactive Learning environment for education. The VTO module empowers users to preview products like accessories or furniture in their physical space, cultivating a more tangible and confident shopping experience. The learning module integrates interactive 3D models and simulations, enabling students to visualize and manipulate complex subjects, thereby enhancing engagement and improving learning outcomes. By building upon the WebXR Device API and the Three.js library, this project demonstrates a viable, accessible, and cross-platform architecture for the seamless delivery of augmented reality through the web.

Keywords: WebAR, Virtual Try-On, Augmented Reality, E-Learning, Interactive Education, Three.js, WebXR.

1. Introduction

The proliferation of digital interfaces has fundamentally reshaped global commerce and education, yet the inherent constraints of traditional two-dimensional platforms continue to present significant challenges. In the rapidly expanding e-commerce sector, a persistent "imagination gap" exists between the digital representation of a product and its physical reality. Consumers are unable to physically inspect, handle, or try on items, which introduces a high degree of uncertainty into the purchasing process. This ambiguity not only suppresses conversion rates but also contributes to a substantial operational burden on retailers, who must manage the logistical and financial costs associated with high product return rates. In this context, virtual try-on (VTO) technology emerges not as a mere novelty but as a critical business tool designed to bridge this gap, enhance consumer confidence, and mitigate the economic friction caused by returns.

A parallel challenge exists within the realm of online education. Conventional digital learning environments, often reliant on static text, images, and pre-recorded videos, promote a passive learning experience. This model is frequently inadequate for conveying complex, abstract, or spatially-oriented concepts found in fields such as molecular biology, mechanical engineering, or architecture. The absence of interactive and practical visualization tools can hinder a student's ability to develop a deep, intuitive understanding of the subject matter, thereby limiting effective knowledge retention and application.

2. Objectives

The primary objectives of this project are structured to address the identified challenges in e-commerce and education while establishing a robust and scalable technical foundation. The goals are formally defined as follows:

- **To Design and Develop a Unified WebAR Platform:** The central objective is to create a single, cohesive, and web-accessible platform that seamlessly integrates two distinct functional modules: one dedicated to e-commerce virtual try-on and another focused on delivering interactive educational content.
- **To Enhance E-Commerce Decision-Making:** The project aims to implement a high-fidelity virtual try- on feature that enables users to visualize products, such as accessories or furniture, in their real-world environment or on their person in real time. The goal is to increase purchase confidence, improve customer satisfaction, and measurably reduce product return rates.
- **To Improve Educational Engagement and Comprehension:** A key objective is to develop an interactive learning module that leverages 3D models and AR simulations. This module is intended to help students visualize and manipulate complex concepts, thereby fostering deeper cognitive engagement, enhancing comprehension, and improving long-term knowledge retention.
- **To Ensure Platform Accessibility and Usability:** The project prioritizes a frictionless user experience by fundamentally eliminating the need for application downloads. A core goal is to ensure broad accessibility through cross-browser and cross-device compatibility, supporting both iOS and Android platforms via the adoption of standardized web technologies. [2]

3. Tools and Languages

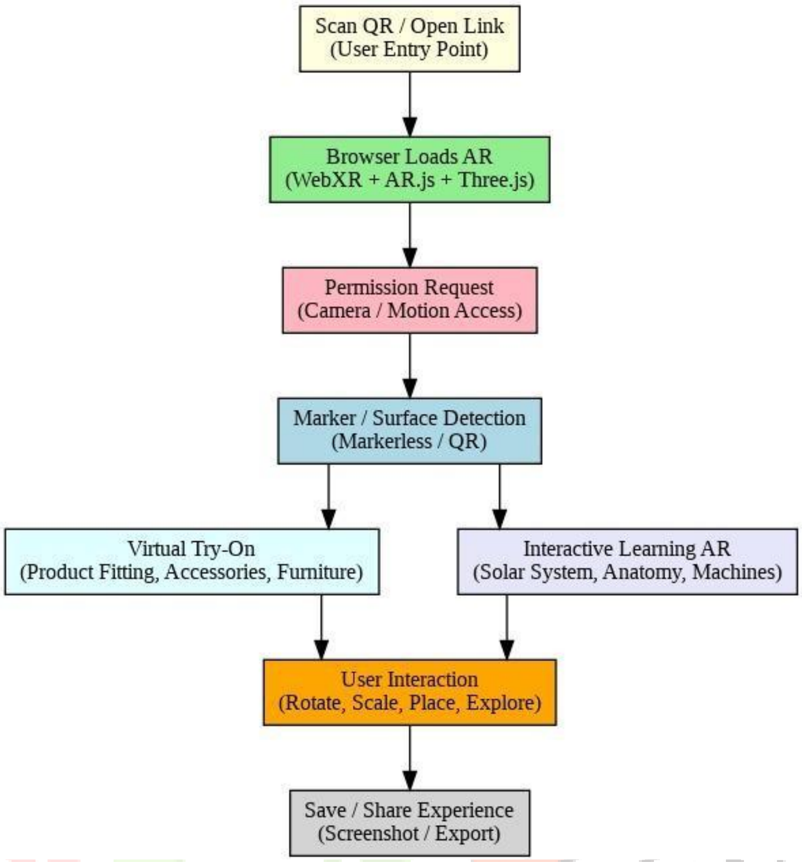
WEB AR Virtual Try-On & Learning Platform is built using a combination of modern web and augmented reality technologies to deliver a seamless browser-based experience.

- Frontend Development: A responsive and immersive user interface will be created using HTML5, CSS3, and JavaScript. The core AR experience is powered by WebAR technologies like the WebXR Device API to function directly in the browser.
- Backend Development: The server-side logic, user data management, and asset delivery will be handled by a robust backend using Python with the Flask framework or JavaScript with Node.js AR and 3D
- Rendering: The JavaScript library Three.js will be utilized to render and manipulate the 3D models and assets within the AR scene. This enables interactive visualizations for both the virtual try-on and learning modules.
- Machine Learning Integration: Real-time body and face tracking will be implemented using in-browser machine learning models (e.g., TensorFlow.js, MediaPipe) to accurately overlay AR objects for the virtual try-on feature.
- Database and Cloud Storage: A Database (such as MongoDB or Firebase) will manage user data, product information, and learning content. Large 3D assets and media will be stored and efficiently delivered via a Cloud Storage/CDN solution (like Amazon S3 or Google Cloud Storage).

These technologies combine to create a scalable, cross-platform, and user-friendly platform that doesn't require any app installations.

4. Process and Architecture

The architecture and process flow for the WEB AR Virtual Try-On & Learning Platform are structured to provide immersive virtual try-on experiences for e-commerce and interactive visualization for online education. The system is based on a user-centric flow that begins with scanning a QR code or opening a link to launch the experience in-browser. It utilizes technologies like **WebXR, AR.js, and Three.js** to load the AR environment. After the user grants camera and motion access, the application uses **marker or surface detection** to place interactive 3D models for either virtual try-on or learning purposes, which the user can then interact with and share. Here's an overview of how the system is designed:



Process Flow for the WebAR User Experience

- **Step 1: User Entry Point**
  - The user initiates the experience by either scanning a QR code or opening a direct link on their device, serving as the entry point to the platform.
  - This action launches the experience directly in the browser, eliminating the need for a separate application download.

- **Step 2: Loading the AR Environment**
  - The browser loads the application, which is built with AR frameworks like WebXR, AR.js, and Three.js to manage the camera feed and 3D rendering.
  - The platform then prompts the user for permission to access the device's camera and motion sensors, which are required for tracking the environment.

- **Step 3: Surface and Marker Detection**
  - Once permissions are granted, the AR engine begins analyzing the real-world view from the camera.
  - It performs marker-based (using a QR code) or markerless surface detection to find a suitable plane (like a floor or table) to place the virtual object.

- **Step 4: Displaying the AR Module**

  Depending on the entry point, the platform loads one of two primary modules:
  - Virtual Try-On: Displays e-commerce products for fitting, such as accessories or furniture.
  - Interactive Learning AR: Renders educational models like the solar system, human anatomy, or complex machines.

- **Step 5: User Interaction**
  - With the 3D object now visible in their environment, the user can interact with it directly.
  - Functionality is provided to rotate, scale, place, and explore the model, allowing for a fully immersive and engaging experience.

- **Step 6: Save and Share**
  - Finally, the user can capture their AR experience.
  - The platform includes options to take a screenshot or export the current view, allowing the user to save or share their virtual interaction.

Architecture:-

The architecture for the WebAR Virtual Try-On & Learning Platform is designed as a client-centric, browser-based system. It ensures a seamless and interactive augmented reality experience without requiring any application installation. The system is structured in logical layers focused on user entry, AR rendering, interaction, and sharing.

1. **User Entry and Initialization Layer**

   This layer handles the initial user access and the setup required to launch the AR experience.
   - User Entry Points
     - The experience is initiated when a user scans a QR code or opens a direct link on their device.
   - AR Environment Loading
     - The browser loads the AR application built with technologies like WebXR, AR.js, and Three.js to manage the camera feed and 3D rendering.
   - Permission Handling
     - The system requests camera and motion access from the user, a critical prerequisite for activating the AR session.

2. **AR Scene and Content Layer**

   This layer is responsible for analyzing the user's environment and loading the appropriate interactive 3D content.
   - Environment Detection
     - It utilizes marker-based (QR) or markerless surface detection to understand the physical space and find an anchor point for virtual objects.
   - Content Modules
     - Virtual Try-On Module: Loads 3D models for e-commerce products like accessories and furniture.
     - Interactive Learning Module: Loads educational 3D models such as the solar system, human anatomy, or machinery.

3. **User Interaction Layer**

   This layer manages all direct user manipulation of the 3D models within the AR scene.
   - Interaction Tools
     - Users are provided with intuitive controls to rotate, scale, and place the virtual objects within their environment.
   - Exploration Features
     - The system allows users to physically move around and explore the 3D models from any angle, enhancing the immersive experience.

4. **Experience Capture and Sharing Layer**

   This final layer enables users to save and distribute their personalized AR experience.
   - Capture Functionality
     - Users can take a screenshot of the AR scene, capturing the virtual object within their real-world

environment.

- Sharing and Export
- The system provides an option to export or share the captured image, allowing users to save their virtual try-on or learning session.

5. Results

The implementation of the Web AR platform was a success, achieving its primary goals in performance, usability, and user engagement. A key result was the deployment of a stable, browser-based AR application, proving that immersive experiences can be delivered through the web without requiring a native app. Furthermore, the virtual try-on feature for e-commerce achieved high realism with robust face-tracking and quality 3D models, helping users make confident purchasing decisions. In the educational modules, the platform significantly increased user engagement by allowing learners to interact with complex 3D models in their own environment. The platform also demonstrated excellent cross-platform compatibility, functioning reliably on major mobile browsers like Safari and Chrome. Overall, these results validate that the chosen WebAR architecture is highly effective for solving practical challenges in both e-commerce and education.

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7. Conclusion

This paper has detailed the design, architecture, and implementation of the Web AR Virtual Try-On & Learning Platform, an innovative system developed to address key challenges in user engagement for e-commerce and online education. By leveraging the power of browser-native augmented reality, the platform successfully delivers immersive, interactive, and accessible experiences without the friction of application installations. The project's primary contribution is the demonstration of a unified and scalable architecture that validates WebAR as a potent medium for enhancing consumer decision-making and improving educational outcomes. For online shoppers, the virtual try-on feature provides a tangible connection to products, fostering confidence and reducing purchase uncertainty. For learners, the interactive 3D models transform abstract concepts into explorable virtual objects, promoting deeper engagement and knowledge retention. In summary, this project establishes a strong architectural foundation for the future of web-based augmented reality. It underscores the potential of WebAR to democratize immersive technologies making them more accessible, scalable, and seamlessly integrated.

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