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AUGMENTED REALITY CAR SHOWCASE

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ABSTRACT
Traditional automotive retail platforms rely on static two-dimensional catalogs that inadequately represent a vehicle's physical scale, spatial context, and customization potential. This limitation often results in reduced user confidence and difficulty in making informed purchasing decisions, particularly when physical showroom visits are not feasible.
This paper presents the Augmented Reality (AR) Car Showcase, a microservice-based mobile system designed to provide an immersive and interactive vehicle exploration experience. The proposed system integrates real-time AR-based projection, dynamic 3D model generation, and a machine learning–driven recommendation module within a unified architecture. This enables users to customize multiple vehicle components, including exterior and interior materials, and visualize life-scale models directly within their physical environment.
The system is implemented using a distributed architecture to ensure scalability and responsiveness, allowing computationally intensive tasks such as 3D rendering and recommendation processing to be handled efficiently. Experimental evaluation demonstrates that the proposed approach enhances user interaction, improves the realism of vehicle visualization, and supports more informed decision-making compared to conventional catalog-based systems.
The results indicate the potential of combining augmented reality, real-time customization, and intelligent recommendation techniques to transform traditional automotive browsing into a more engaging and user-centric digital experience, providing a scalable foundation for next-generation automotive e-commerce platforms.

INTRODUCTION
The Augmented Reality (AR) Car Showcase aims to transform the automotive retail experience by bridging the gap between static digital catalogs and physical showrooms. Conventional online platforms rely heavily on two-dimensional images and videos, which fail to accurately convey a vehicle's physical scale, spatial presence, and design nuances. As a result, users often struggle to visualize how a vehicle would appear in their real-world environment.
This limitation highlights the need for more immersive and interactive visualization techniques. While Augmented Reality has been introduced as a potential solution, existing implementations remain limited in scope. Many current systems are restricted to basic 3D visualization or standalone demonstrations, lacking integration with deeper customization capabilities. In particular, users are often unable to modify specific vehicle components before visualizing them in AR, which reduces the overall effectiveness of the experience.
Furthermore, most existing platforms do not incorporate intelligent recommendation mechanisms. Users are typically required to manually browse through large catalogs without guidance based on their preferences or interaction behavior. This absence of personalized discovery limits the usability and efficiency of current automotive browsing systems.
To address these challenges, this paper proposes the Augmented Reality Car Showcase, a system that integrates environment-aware AR visualization, dynamic 3D customization, and a machine learning–based recommendation engine within a unified mobile framework. By enabling users to interact with and customize vehicles in their own physical space, the system aims to support more informed decision-making. Additionally, the proposed architecture is designed to be scalable and efficient, making it suitable for real-world deployment in next-generation automotive e-commerce platforms

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LITERATURE SURVEY

The application of Augmented Reality (AR) in e commerce has evolved significantly, transitioning from static product displays to more immersive and interactive visualization systems. Early AR applications focused on marker-based tracking techniques to improve spatial perception by enabling virtual object placement in controlled environments. With the advancement of mobile AR technologies, markerless tracking and plane detection have enabled more natural interaction and improved user engagement. However, these systems remain largely limited to visualization and lack support for interactive customization. In parallel, virtual product configuration systems have been developed to allow users to modify product attributes such as color, texture, and materials in real time. While these systems enhance personalization, they are typically confined to standalone 3D viewers and lack integration with real-world AR visualization, preventing users from experiencing customized products within their physical environment. Recommendation systems have also been widely adopted in e-commerce platforms to improve product discovery through techniques such as content-based and collaborative filtering. However, these systems operate independently of visualization technologies and do not utilize spatial interaction data generated during user engagement with AR systems. In the automotive domain, several commercial platforms such as virtual showrooms provided by manufacturers including Renault, Honda, Toyota, and Kia offer interactive vehicle exploration experiences. These platforms typically provide 360-degree views and basic customization features but remain limited in terms of real-time AR integration, deep material-level customization, and intelligent recommendation capabilities within a unified framework. These observations highlight a significant research gap: existing solutions treat visualization, customization, and recommendation as separate components rather than integrating them into a cohesive system. There is a lack of a unified platform that enables real-time customization, environment-aware AR visualization, and personalized recommendation within a single mobile application. To address this gap, the proposed Augmented Reality Car Showcase integrates AR-based visualization, dynamic 3D model customization, and a machine learning–driven recommendation engine within a distributed microservice architecture, enabling a more interactive and user-centric automotive exploration experience.

SYSTEM ARCHITECTURE:

A. Architecture Overview

The Augmented Reality Car Showcase is designed using a distributed microservice-based architecture to ensure scalability and responsiveness. The mobile client interacts with backend services through a centralized Spring Boot API layer, while computationally intensive tasks such as 3D model generation and recommendation processing are offloaded to specialized services as illustrated in Fig. 1.

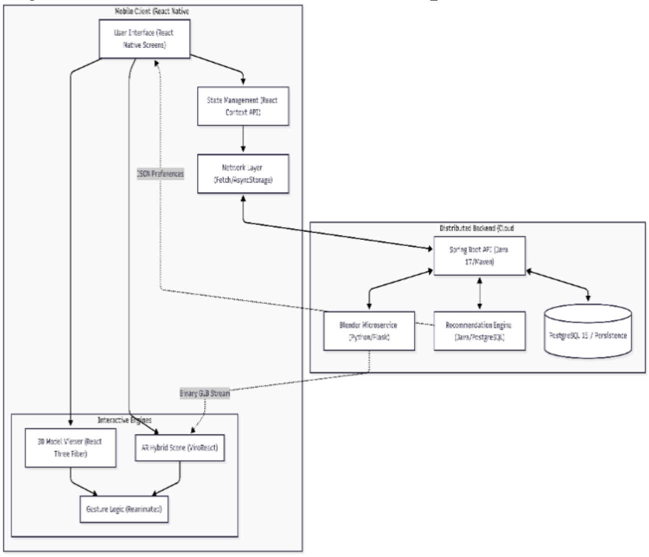

Fig. 1. *System Architecture*

B. Microservices Components

The Spring Boot API Gateway acts as the central orchestration layer, handling request validation, user state management, and service routing via PostgreSQL persistence. The Blender Microservice is a Python/Flask-based service responsible for dynamic 3D asset generation using the Blender Python API (bpy), exporting customized

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.glb files optimized for mobile AR rendering. The Recommendation Engine processes user preferences, query behavior, and spatial session duration to generate personalized vehicle suggestions using a weighted scoring model.

$$S(u,i) = \alpha f_{pref}(u,i) + \beta f_{behavior}(u,i) + \gamma f_{prior}(i)$$

where α, β, and $\gamma$are weighting coefficients for user preference, behavioral patterns, and catalog popularity respectively.

C. System Workflow

The end-to-end interaction follows a six-step Pick-to-Project pipeline: the user selects a base model, customizes seven material slots, the Spring Boot conductor persists the configuration, the Blender service generates the .glb asset, the backend delivers a model link, and ViroReact projects a life-scale vehicle onto the real-world surface, as shown in Fig. 2.

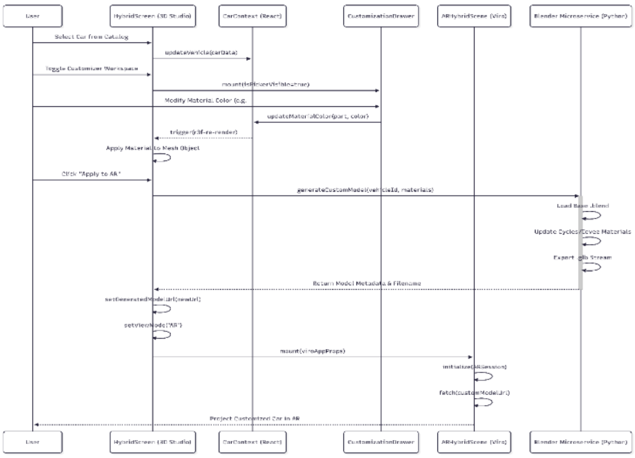

Fig. 2 3D Studio and AR Workflow.

D. Use Case and Recommendation & Search Flow

Fig. 3 presents the use case diagram depicting primary actor interactions. Fig. 4 illustrates the recommendation and search flow between the user, Spring Boot backend, and ML engine.

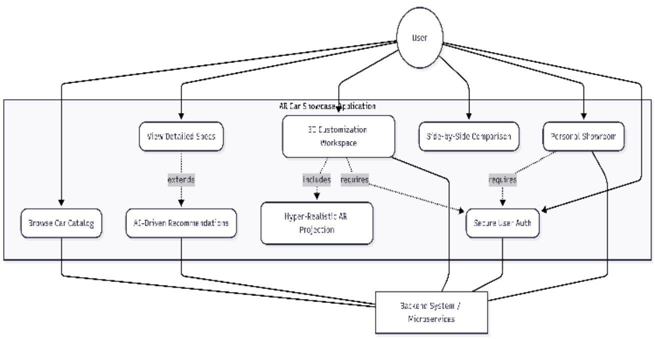

Fig. 3. *Use Case Diagram*

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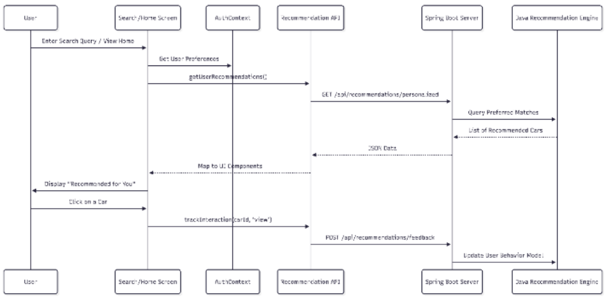

Fig. 4. *Recommendation & Search Flow*

4. IMPLEMENTATION

The implementation of the Augmented Reality Car Showcase is structured as a collaborative "orchestra" of specialized organs, each designed to handle a specific part of the user journey. By using a distributed microservice architecture, the system ensures that heavy computational tasks like 3D rendering and AI processing do not compromise the speed of the mobile application.

A. The Mobile Client

The mobile application is developed using React Native and TypeScript, optimized specifically for Android to ensure stable AR tracking. A hybrid rendering pipeline manages visual output across two stages: React Three Fiber (R3F) is employed during the 3D Studio customization phase, treating 3D objects as declarative states for smooth material updates, while ViroReact handles the final AR projection phase, anchoring life-scale vehicle models onto real-world surfaces such as driveways and garages. The client remains intentionally lightweight by delegating all heavy computation to the Spring Boot backend via typed RESTful API modules

B. Blender Python Microservice

The 3D asset generation service is implemented using Python and Flask, operating a headless instance of Blender 4.0 for automated model processing. Using the Blender Python API (bpy), the service programmatically applies user-defined hexadecimal color values to seven predefined material slots: CAR_BODY_PRIMARY, CAR_BODY_SECONDARY, CAR_INTERIOR_1, CAR_INTERIOR_2, CAR_INTERIOR_3, CAR_RIM, and CARBON_MATERIAL_1. The processed model is exported as a .glb file, a compact format optimized for real-time streaming and AR rendering on the mobile device.

C. Recommendation Engine

The recommendation module processes user preferences, query behavior, and spatial session duration — the time a user spends interacting with a vehicle in AR mode — to generate personalized vehicle suggestions. The relevance score for a user u and item i is computed as:

The relevance score S(u, i) is computed using equation (1), where α, β, and γ balance user preferences, behavioral patterns, and general catalog popularity respectively.

D. API and Data Flow

Communication between the mobile client and backend services is managed through RESTful APIs. Each customization request carries the selected vehicle identifier and material configuration parameters, which the Spring Boot conductor validates, persists in PostgreSQL, and routes to the appropriate microservice for processing.

E. Pick-to-Project Execution Workflow

The end-to-end workflow follows a structured six-step
pipeline: (1) the user selects a base vehicle from the catalog, (2) customization parameters are defined across seven material slots, (3) the Spring Boot backend persists the configuration and triggers the Blender service, (4) the Blender microservice generates the customized .glb model, (5) the backend delivers a model link to the mobile client, and (6) ViroReact projects the life-scale vehicle into the user's real-world environment.

5. TESTING AND VALIDATION

To evaluate the performance and reliability of the proposed system, testing was conducted across four key dimensions: system performance, visual accuracy, AR stability, and overall interaction quality as summarized in Table I.

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A. System Performance

The Spring Boot backend was subjected to concurrent request testing to evaluate API responsiveness, request handling consistency, and session data isolation under simultaneous multi-user conditions. Simulated concurrent requests were issued across five endpoints: vehicle catalog retrieval, specification lookup, customization model generation, recommendation processing, and configuration persistence. The results confirmed stable response behavior with no observed data conflicts between user sessions, validating the integrity of the PostgreSQL-backed orchestration layer.

B. Visual Accuracy

The fidelity of the dynamic 3D customization pipeline was validated by comparing user-selected hexadecimal color values against the corresponding material outputs in the generated .glb models. Color values were transmitted from the React Native client to the Blender microservice, where the Blender Python API (bpy) applied them to seven predefined material slots. Visual cross-checks confirmed that the rendered models accurately reflected the input configurations across all material slots, including CAR_BODY_PRIMARY, CAR_RIM, and CAR_INTERIOR variants.

C. AR Stability and Spatial Accuracy

The AR projection module was evaluated across three distinct environmental conditions: controlled indoor settings, semi-outdoor environments such as garages, and open outdoor spaces including driveways and parking areas. Surface detection via the ViroReact plane detection framework was confirmed successful across all tested environments under varying lighting conditions. Once anchored, vehicle models maintained stable placement without observable drift during device movement. Spatial proportions of projected models were cross-validated against real-world vehicle dimensions, confirming life-scale accuracy of the AR visualization.

D. Overall Interaction Performance

The complete Pick-to-Project workflow — from vehicle selection and material customization to .glb generation and AR projection — was evaluated for end-to-end responsiveness. The offloading of computationally intensive tasks to backend microservices ensured that the React Native client maintained a fluid and responsive user experience throughout all interaction stages, with minimal perceptible latency between customization input and model delivery.

TABLE I. Evaluation Summary

Metrics	**Observation**
API Response	Stable under concurrent load
Model Generation	Completed for all requests
Colour Accuracy	Matches input hex values
AR Surface Detection	Successful across 3 environments
AR Stability	No drift observed post-placement
Spatial Accuracy	Life-scale proportions validated

6. Experimental Results

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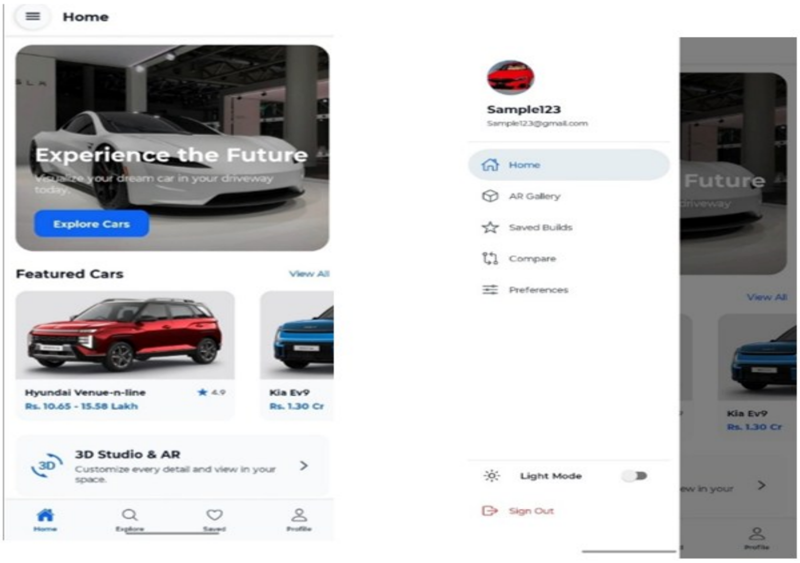

Fig. 5. AR Car Showcase mobile application home screen displaying featured vehicles, catalog browsing, and 3D Studio navigation.

Fig. 6. Augmented reality projection of MG Cyberster in outdoor environment: (a) angled side view, (b) top-down view demonstrating life-scale spatial placement.

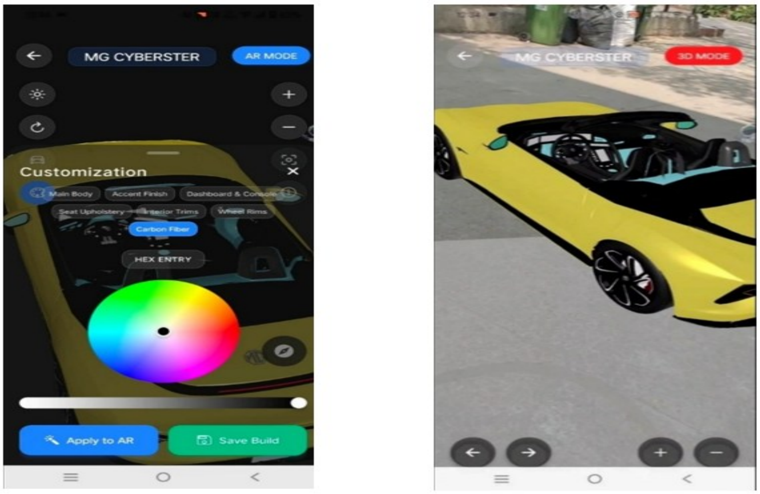

Fig. 7. 3D Studio customization interface: (a) color wheel and material slot selection panel, (b) customized MG Cyberster preview after applying user-defined color

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Fig. 8. Augmented reality projection of Maruti Brezza in outdoor environment: (a) rear view, (b) front view confirming stable surface detection and model accuracy.

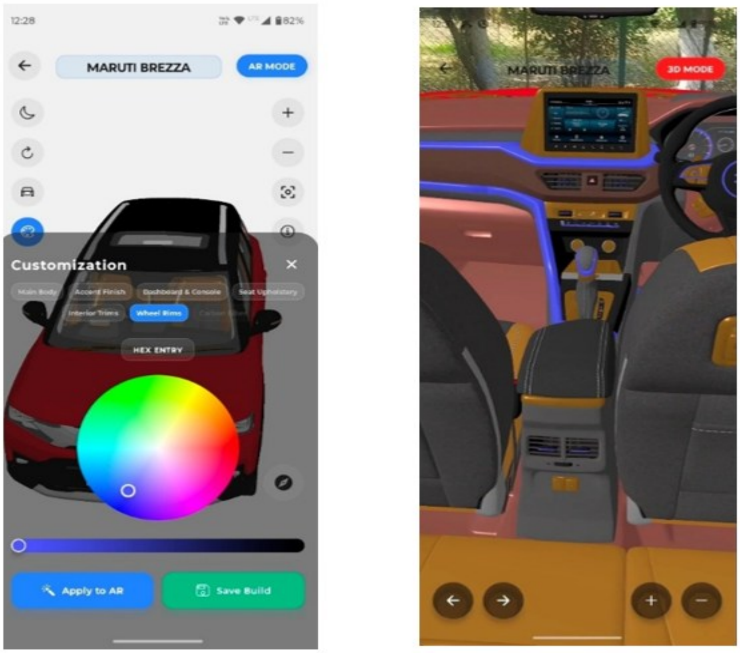

Fig. 9. 3D Studio customization interface: (a) color wheel and material slot selection panel, (b) customized Maruti Brezza preview after applying user-defined color values.

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7. CONCLUSION

The Augmented Reality Car Showcase presents an integrated approach to transforming automotive retail by enabling immersive visualization, real-time customization, and intelligent recommendation within a unified mobile platform. By addressing the limitations of traditional two dimensional catalogs, the system allows users to explore and evaluate vehicles in a more realistic and context-aware manner. The proposed solution combines Augmented Reality (AR), dynamic 3D model generation, and a microservice based architecture to deliver a responsive and scalable user experience. Users can customize multiple vehicle components and visualize life-scale models in real-world environments, supporting more informed purchase decisions. The system demonstrates the effectiveness of distributing computational tasks across specialized backend services — including Blender-based rendering and ML-based recommendation — while maintaining mobile performance. The proposed framework establishes a practical foundation for next-generation automotive e-commerce platforms.

Future Enhancement:

Future enhancements include multi-vehicle support extending the platform to motorcycles and commercial vehicles; real-time multi-user AR enabling shared visualization across devices; VR integration for fully immersive showroom environments; spatial audio simulation incorporating engine acoustics; voice-based customization via natural language interfaces; and cross-domain adaptation for industries such as furniture, real estate, and consumer products.

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