

# Web-based Augmented Reality and Hybrid Recommendation for Furniture Visualization and Personalized Suggestions

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## Abstract

In the Philippine e-commerce fields, traditional 2D product visualization often fails to convey the scale and texture of handcrafted furniture, leading to customer dissatisfaction and frequent returns. This study developed a Web-Based Augmented Reality (AR) and Hybrid Recommendation System for Simeon Home Furniture to address these visualization gaps and provide personalized suggestions and improve shopping experiences. Utilizing a descriptive-developmental research design and the Iterative Waterfall Model, the system was built using Laravel, MySQL, and ARCore/ARKit. The architecture integrates a hybrid recommendation engine combining collaborative and content-based filtering with fallback logic to mitigate "cold start" data issues. Evaluation of the system was conducted via alpha and beta testing based on ISO/IEC 25010 standards. Results from IT experts indicated a high level of effectiveness with an overall weighted mean of 3.6 (86.7%), with Compatibility scoring the highest at 3.9. The average score for user acceptance testing among furniture buyers was 3.6 (90%), and the average score for usability was 3.7 (92.5%), which shows that the system's interface is easy to use. The findings confirm that the transition from static social media images to immersive AR previews effectively eliminates the "visualization gap," reducing the need for physical store visits and home measurements. The study concludes that integrating AR with robust data-driven recommendation logic significantly enhances consumer confidence and operational efficiency in the furniture retail sector.

## INTRODUCTION

In today's digital age, e-commerce has transformed consumer behavior, particularly in the Philippines where online marketplaces have become integral to daily life. The pandemic accelerated this shift, with 57% of Filipino respondents reporting weekly online purchases, including furniture. Yet, despite this growth, online furniture shopping continues to face challenges: customers cannot physically test products, struggle to visualize them in their own spaces, and often encounter misleading 2D representations that lead to dissatisfaction, costly returns, and weakened trust in digital platforms. As Fast Company (2022) noted, "brands get to sell furniture that looks stellar in 2D but doesn't always live up to your expectations in 3D," underscoring the systemic issue of misleading visuals in online retail. To address these limitations, emerging technologies such as Augmented Reality (AR) offer promising solutions. AR enables customers to project three-dimensional furniture models into their own environment, enhancing product comprehension and confidence in purchase decisions. Complementing this, hybrid recommendation systems—combining collaborative filtering and content-based filtering—that provide personalized suggestions to improve relevance and reduce mismatches. Together, AR visualization and intelligent

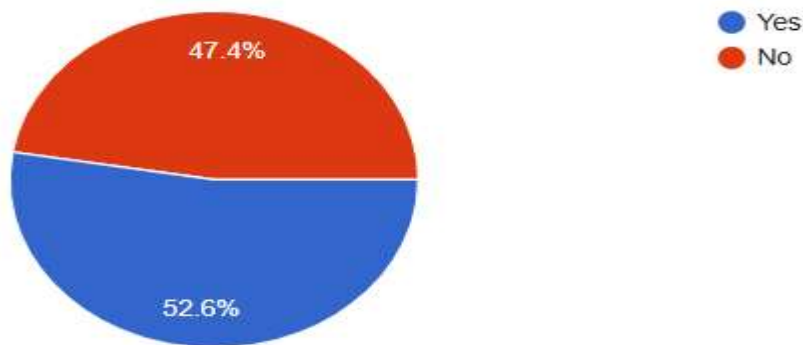
recommendation engines create a more engaging, accurate, and trustworthy shopping experience. Theoretical foundations for this study draw from Chaudhry et al.'s (2023) Augmented Reality Behavioral Framework, which highlights the role of interactivity, enjoyment, and perceived utility in shaping consumer purchase intentions, and Sajid et al.'s (2025) hybrid recommendation model, which addresses cold-start and sparsity problems in user-item interactions. Integrating these frameworks, the proposed system leverages immersive AR visualization alongside intelligent recommendation to enhance consumer engagement, reduce product returns, and strengthen trust in online furniture shopping. Related literature supports this approach. Studies on AR in retail (Sambrani, 2023; Phade et al., 2024) demonstrate increased satisfaction and confidence among users who can visualize products in their own spaces, while research by Barta et al. (2022) and Lee (2022) shows AR's effectiveness in reducing cognitive dissonance and perceived risk. Similarly, hybrid recommendation systems (Patil et al., 2024; Sultana & Begum, 2021; Aljunid & Huchaiyah, 2021) have proven effective in overcoming the limitations of traditional collaborative filtering, ensuring personalized and scalable recommendations even under sparse data conditions. These findings collectively highlight the potential of integrating AR visualization with hybrid recommendation to address persistent challenges in online furniture retail. Therefore, this study developed a Web-Based Augmented Reality and Hybrid Recommendation System for Furniture Visualization and Personalized Suggestions, tailored for Simeon Home Furniture. The system aims to reduce mismatches, improve customer satisfaction, and enhance marketing engagement by combining immersive AR product visualization with intelligent recommendation algorithms. By evaluating its effectiveness through ISO 25010 standards and user acceptance, the research seeks to contribute both practical solutions for furniture businesses and conceptual insights for future researchers exploring AR-driven e-commerce systems.

## METHODS

This study utilized a descriptive-developmental design with a qualitative approach to develop and assess product visualization and personalized recommendation in a web-based application. The descriptive phase identified existing resources, technological tools, and user behaviors in online furniture retail, while the developmental phase focused on designing and building a functional prototype capable of rendering AR 3D images and generating intelligent recommendations. The population was based on the client's monthly order volume of approximately 20 customers. The resulting sample size was 19 individual purchasers, purposively selected to represent actual users of online furniture platforms. In addition, IT experts were engaged to evaluate system effectiveness, while the owner, social media manager, and individual buyers served as respondents for user acceptance testing. Data were gathered through Likert-scale surveys aligned with ISO/IEC 25010 standards, administered both digitally and in print. Primary data focused on user perceptions of functional suitability, usability, performance efficiency, reliability, and security, while secondary data were drawn from published literature and online databases related to augmented reality in e-commerce and recommendation systems. Testing procedures included alpha testing with IT experts to assess functional suitability, maintainability, performance efficiency, compatibility, reliability, and security, followed by beta testing with end users to evaluate functional suitability, usability, performance efficiency, and reliability. Survey responses were analyzed using the weighted mean formula, with results interpreted according to standard ranges (e.g., 3.26–4.00 = very satisfied, 2.51–3.25 = satisfied). This non-experimental approach avoided variable manipulation, instead observing naturally occurring interactions, perceptions, and outcomes through criterion-based evaluation aligned with ISO/IEC 25010 standards.

## RESULTS AND DISCUSSION

This section presents the gathered data analyzed and interpreted to determine the technical effectiveness and user acceptance of AR recommendation. The framework of the analysis and interpretation is guided by the specific research questions established in the introduction, focusing on the system’s capacity to visualize the furniture product of Simeon Home Furniture through Augmented Reality and to generate a personalize recommendation for each user using Hybrid recommendation (Collaborative Filtering + Content-Based Filtering).



**Figure 1: User Experience with Augmented Reality Systems**

Figure 1 presents the survey results regarding prior experience with augmented reality (AR) systems. Out of 19 respondents, 10 (52.6%) reported having used an AR 3D model before, while the remaining 9 (47.4%) indicated no prior experience. These findings provide valuable insight into the participants’ familiarity with AR technology, which can guide improvements in the functionality and usability of the developed system. In particular, understanding the balance between experienced and inexperienced users highlights the need for intuitive navigation features to ensure accessibility for all users.

**Table 1: Tabulated Results of level of Effectiveness in terms of Functional Suitability**

Description	Weighted Mean	Interpretation
The function provides the correct results with the needed degree of precision.	3.8	Highly Suitable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.8</b>	<b>Suitable</b>

Table 1 presents IT experts’ evaluation of AR recommendation systems functionality, with an average weighted mean of 3.8 (Highly Suitable). The results indicate that the system is performing at an effective level. The high mean score of 3.8 suggests that users or evaluators are very satisfied with the system’s ability to provide precise and correct results, meeting the necessary functional requirements.

**Table 2: Tabulated Results of level of Effectiveness in terms of Performance Efficiency**

Description	Weighted Mean	Interpretation
The maximum limits of the product or system parameter meet requirements.	3.6	Highly Efficient

**AVERAGE WEIGHTED MEAN**

**3.6**

**Highly Efficient**

Table 2 presents IT experts' evaluation of AR recommendation systems Performance Efficiency, with an average weighted mean of 3.6 (Highly Efficient). The results indicate that the system's technical parameters and capacity limits successfully meet all requirements. This suggests the system is well-optimized and capable of handling its intended workload without performance degradation.

**Table 3: Tabulated Results of level of Effectiveness in terms of Maintainability**

<b>Description</b>	<b>Weighted Mean</b>	<b>Interpretation</b>
A system or computer program is composed of discrete components such that a change to one component has minimal impact on other components	3.8	Highly Maintainable
A system or product can be used in more than one system or in building another system.	3.8	Highly Maintainable
The product or system can be analyzed or understood. It relates to the ease with which information can be examined, broken down, and evaluated for the purpose of gaining insights, identifying patterns, or making informed decisions.	3.8	Highly Maintainable
The product or system can be changed with ease. It can be modified, adapted, or extended without causing unintended side effects or significant disruptions to its functionality	3.6	Highly Maintainable
The product or system can be effectively and efficiently tested. It measures the ease with which tests can be designed, executed, and evaluated to assess the system's functionality, performance, and adherence to requirements.	3.8	Highly Maintainable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.76</b>	<b>Highly Maintainable</b>

Table 3 presents IT experts' evaluation of AR recommendation systems Maintainability with an average weighted mean of 3.76 (Highly Maintainable). The evaluation of Maintainability yielded an Average Weighted Mean of 3.76, indicating that the system architecture is effective, robust, sustainable, and developer friendly. Key insights include a high score of 3.8 in Modularity, Reusability, and Analyzability,

suggesting a well-structured software design that allows for component reuse and analysis without compromising system integrity. Additionally, the system's high testability, with a mean score of 3.8, ensures efficient validation of future updates against quality standards. Although Modifiability received the lowest score at 3.6, it still falls within the "Very Satisfied" range, indicating that modifications are relatively straightforward, though slightly more complex than analysis or testing. Overall, the system is deemed highly maintainable, with its modular design ensuring stability and adaptability for future needs.

**Table 4: Tabulated Results of level of Effectiveness in terms of Compatibility**

<b>Description</b>	<b>Weighted Mean</b>	<b>Interpretation</b>
The product or system can function together without conflicts or disruptions, enabling seamless interaction and data exchange while maintaining their individual functionalities	3.8	Highly Compatible
The product or system can function together to promote seamless communication, data sharing, and collaboration between different systems, allowing them to operate together effectively and achieve common goals.	3.8	Highly Compatible
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.8</b>	<b>Highly Compatible</b>

Table 4 presents IT experts' evaluation of AR recommendation systems Compatibility, with an average weighted mean of 3.8 (Highly Compatible), indicating an effective level of technical effectiveness between the system and other components. The system demonstrated a conflict-free operation, maintaining functionality while exchanging data, critical for preventing crashes in multi-tool environments. It also scored 3.8 in seamless interoperability, indicating its architecture uses standardized protocols for smooth communication with external systems, facilitating collaboration across platforms. Overall, the findings highlight the system's exceptional compatibility, making it reliable for integrated workflows.

**Table 5: Tabulated Results of level of Effectiveness in terms of Reliability**

<b>Description</b>	<b>Weighted Mean</b>	<b>Interpretation</b>
Despite the presence of hardware or software issues, a system, product, or component functions as intended.	3.4	Highly Reliable
In the event of an interruption or a failure, a product or system can recover the data to establish the desired state of the system.	3.4	Highly Reliable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.4</b>	<b>Highly Reliable</b>

Table 5 presents IT experts' evaluation of AR recommendation systems Reliability, with an average weighted mean of 3.4 (Highly Reliable), indicating the system is effectively dependable. Key insights reveal resilience to errors, with a score of 3.4 for fault tolerance, allowing continued operation despite minor issues. The same score for recoverability underscores the system's ability to protect user data and restore functionality after disruptions. Both criteria received equal scores, demonstrating balanced reliability. Although this score is slightly lower than those for Functionality or Compatibility, it remains categorized as "Effective" and "Very Satisfied," with effective protections for error handling and data recovery.

**Table 6: Tabulated Results of level of Effectiveness in terms of Security**

Description	Weighted Mean	Interpretation
The product or system protects the data by regulating its accessibility. Users have data restrictions.	3.8	Highly Secure
In the event of an interruption or a failure, a product or system can recover the data to establish the desired state of the system.	3.6	Highly Secure
Actions or events can be proven to have taken place so that the events or actions cannot be repudiated later.	3.8	Highly Secure
The product or system has the capability of pointing out what happens to the system.	3.6	Highly Secure
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.65</b>	Highly Secure

Table 6 presents IT experts' evaluation of AR recommendation systems Security yields a consistently high level of user approval across all measured parameters. With an Average Weighted Mean of 3.65, the system is interpreted as Highly Secure.

**Table 7: Tabulated Results of level of User Acceptance in terms of Functional Suitability**

Description	Weighted Mean	Interpretation
The system provides complete features for furniture visualization and personalized recommendations.	3.58	Highly Suitable
The augmented reality 3D models accurately represent the furniture products.	3.63	Highly Suitable
The hybrid recommendation system generates suggestions that are appropriate to my preferences.	3.58	Highly Suitable

The system’s functions meet the practical needs of customers and store owners.	3.58	Highly Suitable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.59</b>	Highly Suitable

Table 7 presents SFH Owner / Social Media Manager and Individual Purchaser evaluation of the AR recommendation system's level of acceptance in terms of Functional Suitability with an average weighted mean of 3.59, which corresponds to a verbal interpretation of Highly Suitable. The findings indicate that the system's ability to accurately represent furniture products through augmented reality (AR) 3D models received the highest rating of 3.63, suggesting that the visual fidelity and realism of the models are major strengths. Other critical features, including the completeness of furniture visualization, the appropriateness of the hybrid recommendation engine, and the alignment of functions with the practical needs of both customers and store owners, all maintained consistent scores of 3.58. These results collectively demonstrate that the system effectively fulfills its intended purpose by providing a functional, reliable, and user-centric platform that meets the high standards established by the ISO/IEC 25010:2025 criteria.

**Table 8: Tabulated Results of level of User Acceptance in terms of Performance Efficiency**

Description	Weighted Mean	Interpretation
The augmented reality visualization loads quickly and smoothly	3.42	Highly Efficient
The recommendation results are generated within a reasonable time.	3.47	Highly Efficient
The system operates efficiently without consuming excessive device resources.	3.58	Highly Efficient
The system maintains good performance even when handling multiple furniture products or large datasets	3.53	Highly Efficient
The system remains stable and does not lag even with multiple users.	3.47	Highly Efficient
The system responds quickly when ordering or managing the customer order.	3.74	Highly Efficient
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.54</b>	<b>Highly Efficient</b>

Table 8 presents SFH Owner / Social Media Manager and Individual Purchaser evaluation of the AR recommendation system’s Performance Efficiency with an average weighted mean of 3.54, indicating that the platform is Highly Efficient. The highest-rated attribute is the system's responsiveness during order management, which achieved a significant score of 3.74, reflecting a seamless transition from visualization to transaction. Additionally, the system demonstrates strong optimization in resource management (3.58) and scalability when handling large datasets (3.53). While the loading speed of AR visualizations and general system stability during multi-user sessions received slightly lower (yet still

high) scores of 3.42 and 3.47, respectively, all parameters remain firmly within the "Highly Efficient" verbal interpretation. Overall, these findings suggest that the system provides a high-speed, stable, and resource-efficient experience that meets the rigorous demands of real-time augmented reality and recommendation processing.

**Table 9: Tabulated Results of level of User Acceptance in terms of Usability**

Description	Weighted Mean	Interpretation
The system is easy to learn and understand.	3.74	Highly Usable
The interface design is visually appealing and enhances the AR experience.	3.68	Highly Usable
The system provides helpful error messages or guidance when incorrect inputs are made.	3.63	Highly Usable
The system provides clear instructions and feedback during use.	3.63	Highly Usable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.67</b>	<b>Highly Usable</b>

Table 9 presents SFH Owner / Social Media Manager and Individual Purchaser evaluation of the AR recommendation system’s Performance Efficiency with an average weighted mean of 3.54, indicating that the platform is Highly Usable, however, the data specifically regarding Usability shows an even higher Average Weighted Mean of 3.67, interpreted as Highly Usable. The most notable finding is the system's ease of learning and understanding, which earned the highest score of 3.74, suggesting a very shallow learning curve for new users. The visual appeal of the interface design also scored remarkably high at 3.68, confirming that the UI successfully enhances the overall augmented reality experience. While the provision of error messages, guidance, and clear feedback received slightly lower scores of 3.63, they remain firmly within the "Highly Usable" category. Collectively, these results indicate that the system is not only technically efficient but also prioritizes a user-centric design that is intuitive, aesthetically pleasing, and supportive during operation.

**Table 10: Tabulated Results of level of User Acceptance in terms of Reliability**

Description	Weighted Mean	Interpretation
The system operates smoothly without frequent errors or crashes.	3.53	Highly Reliable
The AR visualization and recommendation features are consistently available when needed.	3.53	Highly Reliable
The results and recommendations are dependable and logically consistent.	3.47	Highly Reliable

I trust the system to function reliably for furniture visualization and personalized suggestions.	3.63	Highly Reliable
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.54</b>	<b>Highly Reliable</b>

Table 10 presents SFH Owner / Social Media Manager and Individual Purchaser evaluation of the AR recommendation system’s Reliability with an average weighted mean of 3.54, indicating that the platform is Highly Reliable. The data reveals that user trust in the system's ability to function reliably for furniture visualization and personalized suggestions is particularly strong, earning the highest individual score of 3.63. Both the smooth operation of the system without frequent crashes and the consistent availability of AR features were rated equally at 3.53, further solidifying the system's dependable nature. Although the logical consistency of results and recommendations received a slightly lower mean of 3.47, the overall assessment remains very high, demonstrating that the system provides a stable and trustworthy environment for both visualization and decision-making processes.

**Table 11: Summary Results of level of Effectiveness (IT Experts)**

ISO/IEC 25010:2025 Criteria	Average Weighted Mean	Verbal Interpretation
Functional Suitability	3.8	Very Satisfied
Performance Efficiency	3.6	Very Satisfied
Maintainability	3.8	Very Satisfied
Compatibility	3.9	Very Satisfied
Reliability	3.4	Very Satisfied
Security	3.6	Very Satisfied
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.6</b>	<b>Highly Effective</b>

Table 1 summarizes the IT experts’ evaluation of the Simeon Home Furniture AR and Hybrid Recommendation System level of effectiveness using ISO/IEC 25010 quality characteristics. The system achieved an overall weighted mean of 3.6, interpreted as *Very Satisfied*, which corresponds to an effectiveness rating of 86.7%. Among the criteria, compatibility (3.9) and functional suitability (3.8) received the highest ratings, confirming that the system integrates well with existing platforms and delivers accurate product visualization and personalized recommendations. Performance efficiency (3.6) and security (3.6) also scored positively, indicating that the system processes tasks reliably while maintaining adequate safeguards for user data. Meanwhile, reliability (3.4), though slightly lower, still reflects a strong level of satisfaction, suggesting that occasional operational errors do not critically affect system performance. The overall effectiveness rating of 86.7% aligns with prior studies applying ISO/IEC 25010 in similar contexts. For instance, Stefani et al. (2023) reported that B2C platforms achieved *Very Satisfied* ratings in functional suitability and compatibility, with effectiveness ranging between 85–90%. This highlights the consistency of results across different systems and confirms that the Simeon Home Furniture AR and Hybrid Recommendation System deliver robust effectiveness in product visualization and personalized recommendations. Additionally, the findings show the system’s practical reliability for end-users while also contributing valuable insights for future research in augmented reality and hybrid recommendation technologies.

**Table 12: Summary Results of level of User Acceptance  
(Simeon Home Furniture Owner, Social Media Manager and Individual Purchaser)**

ISO/IEC 25010:2025 Criteria	Average Mean	Weighted	Verbal Interpretation
Functional Suitability	3.59		Strongly Agree
Performance Efficiency	3.54		Strongly Agree
Usability	3.67		Strongly Agree
Reliability	3.54		Strongly Agree
<b>AVERAGE WEIGHTED MEAN</b>	<b>3.59</b>		<b>Highly Accepted</b>

Table 2 summarizes the Simeon home furniture owner, social media manager and individual purchaser evaluation of AR recommendation user acceptance based on ISO/IEC 25010 characteristics. The overall weighted mean was 3.6, interpreted as *Highly Accepted*, which corresponds to 90% user acceptance. Among the criteria, usability received the highest rating (3.7 or 92.5%), showing that users found the system intuitive, easy to navigate, and supportive of their tasks. Reliability had the lowest rating (3.5 or 87.5%), but still indicates that users consider the system dependable, with only minor areas for improvement. The remaining characteristics, such as functional suitability and performance efficiency are both scored 3.6 (90%), confirming that the system meets expectations in terms of completeness, appropriateness, and efficient resource use. Overall, the results demonstrate that the system is well-accepted by users and meets the applied functions under ISO/IEC 25010 standards. The remaining 10% represents opportunities for improvement, as system functionalities may evolve and adapt with the new technologies.

**Table 13: Composite Validation of System Effectiveness**

Respondent Group	Evaluative Perspective	Grand Weighted Mean	Verbal Interpretation	Validation Verdict
IT Experts	Technical Quality (ISO/IEC 25010:2023)	3.6	Highly Effective	VALID
SFH Owner, Social Media Manager and Individual Purchaser	User Experience & Acceptance (ISO/IEC 25010:2023)	3.59	Highly Accepted	VALID

Table 13 presents the composite validation of the AR recommendation system's effectiveness across the two respondent groups, yielding consistently positive grand weighted means and VALID verdicts for all perspectives. The IT Experts evaluated the technical quality based on ISO/IEC 25010:2023 standards, resulting in a Grand Weighted Mean of 3.6, which is interpreted as Highly Effective. Similarly, the group consisting of the SFH Owner, Social Media Manager, and Individual Purchasers assessed the user experience and acceptance, producing a nearly identical Grand Weighted Mean of 3.59, interpreted as Highly Accepted. These results indicate a strong consensus between technical specialists and end-users,

confirming that the system is not only robust from a software engineering standpoint but also highly practical and desirable for its target audience.

## CONCLUSSIONS AND RECOMMENDATIONS

The study revealed that Simeon Home Furniture's traditional ordering system, while organized, suffered from inefficiencies in visualization and documentation. Static images and manual records often led to mismatches in customer expectations, resulting in frequent product returns. The integration of web-based augmented reality (AR) and a hybrid recommendation system effectively addressed these limitations by enabling customers to visualize furniture in their own spaces, thereby reducing uncertainty and enhancing confidence in purchase decisions. The relational database schema, with its normalized structure and pivot tables, proved essential in managing complex product attributes and supporting recommendation accuracy. Moreover, the hybrid recommendation engine, combining collaborative and content-based filtering, demonstrated resilience against cold-start and data sparsity issues, ensuring robust personalization. IT experts and users alike rated the system highly, with effectiveness and acceptance levels exceeding 85%, though reliability remained a minor limitation. The findings show that AR-driven visualization and hybrid recommendation systems can greatly improve customer satisfaction and operational efficiency in furniture retail. Still, the study notes its limits, since results are based only on Simeon Home Furniture's context and need wider validation. Future researchers are encouraged to explore advanced AI rendering, cross-platform AR compatibility, and stronger data privacy frameworks to make these systems more scalable and trustworthy. Based on the conclusions, several practical recommendations are suggested for Simeon Home Furniture and future researchers. For the company, adopting a centralized relational database, optimized fallback logic, and expanded user-event tracking will help reduce documentation errors, improve recommendation accuracy, and strengthen system reliability. These steps can boost customer confidence and lower product returns. Simeon Home Furniture should also move from manual Google Sheets to the Admin Inventory and Order Modules, provide interactive onboarding tutorials to reduce the learning curve for new users, and track deeper behavioral metrics such as dwell time on AR models to refine personalization. For future researchers, areas worth exploring include machine learning-based rendering for realistic 3D models, reinforcement learning-driven recommendation algorithms, and AR-based room measurement features to ensure accurate furniture fitting.

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