EVALUATING THE IMPACT OF AUGMENTED REALITY ON ONLINE SHOPPING EXPERIENCE: A STUDY IN CHENNAI CITY

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***Abstract* - Since augmented reality (AR) improves customer interaction and decision-making, including it into online business has completely changed the shopping online experience. Sometimes traditional online buying methods lack interactive components, which might result in lower consumer confidence and increased customer returns. AR solves this by offering an immersive and real-time visual of products, so enabling customers to make well-informed purchase decisions. This paper aims to investigate, by means of an analysis of its effects on user satisfaction, purchase intention, and conversion rates, the efficacy of augmented reality (AR) in online shopping experiences within Chennai. Examining the data gathered from a total of five hundred online customers using statistical methods and structured questions, According to the results, 65% of respondents said their uncertainty about completing transactions had dropped; 78% of them claimed their confidence in making purchase decisions had grown. Moreover, AR-integrated shopping systems improved 42% more conversion rates than traditional e-commerce interfaces.**

Keywords - Augmented Reality, Online Shopping, Consumer Engagement, E-commerce, Chennai

I. INTRODUCTION

Augmented reality (AR) has become a game-changing tool providing consumers interactive and immersive shopping experiences in the realm of online retailing. Using AR [1] consumers may view items in real-world surroundings before making a purchase, unlike traditional online buying which depends on still images and descriptions. Advances in mobile computing, artificial intelligence, and cloud-based processing have tremendously hastened the acceptance of AR in retail, which has let for seamless integration into e-commerce platforms [2]. Research on AR shopping reveal better decision-making, lower return rates, and more customer involvement. This addresses significant shortcomings of current online purchasing methods [3].

Although augmented reality presents many opportunities, its general use in online buying is hampered in many different ways. About accessibility, one of the most crucial challenges is technological compatibility. This is thus since not all consumer products or online shopping systems allow augmented reality aspects [4]. Smooth interaction and realistic augmented reality models depend on high hardware and software investments [5]. Another challenge is the great expenses linked to development. Moreover, the challenges are user adoption and familiarity since many consumers might be reluctant to use augmented reality tools for shopping since they are still not familiar with them [6]. Moreover, the extensive application of computer vision and real-time analytics increases questions regarding data privacy since it calls for issues regarding the approach of consumer data collecting and storage [7].

In local markets like Chennai, we understudied how well AR enhances consumer experiences and shapes buying behavior. This is true despite AR finds interesting applications in e-commerce. Localized studies looking at how augmented reality affects user engagement, conversion rates, and purchase confidence in Indian metropolitan centers devoid of [8] lack Global studies have underlined the possibilities of augmented reality by stressing its potential. This study intends to close this gap by analyzing AR-based shopping experiences in Chennai. The study will take into account several important performance criteria including return lowering, transaction completion rates, and customer satisfaction.

The primary objectives of this research are:

- To learn consumer impressions of AR integrated online buying systems.
- To learn how AR influences confidence with which one approaches decisions and intention to buy.
- To find how effectively AR might lower product return rates and increase conversion rates
- To send recommendations to online stores wishing to implement AR-based shopping solutions.

This paper provides empirical study of AR's acceptance in a developing market, so contributing to the expanding field of AR in online commerce. Unlike earlier research mostly on global markets, the present one examines the regional dynamics of AR adoption in Chennai's online retail environment. The study also uses a quantitative method including statistical analysis and the distribution of structured surveys in order to provide verifiable evidence of the success of AR. For businesses engaged in e-commerce, the findings have pragmatic effects since they will enable them to maximize artificial intelligence-driven strategies for customer interaction. This paper addresses technological, financial, and behavioral factors to support a more whole knowledge of the part AR performs in improving digital shopping experiences.

II. RELATED WORKS

Using AR to online buying has drawn a lot of attention lately. AR has shown several studies to increase consumer involvement by providing interactive experiences not possible on conventional online buying systems [6]. By letting customers see items in real-time surroundings, AR helps them to feel more confident about their purchase decisions. Studies show that AR elements, such virtual try-ons for clothes and accessories, help consumers feel more delighted with their purchases and reduce their degree of uncertainty when making decisions [7].

Many studies have examined the psychological and behavioral effects of AR-based shopping interactions. Studies show that AR helps consumers to feel more in control of their purchases, so increasing the likelihood that they will complete their transactions [8]. Consumers who interacted with AR enhanced interfaces were forty percent more likely to finish their purchases than were consumers who used traditional e-commerce platforms [9]. Moreover, AR reduces the mental effort required for product evaluation, hence reducing the return rates for purchases driven by AR by 35 percent [10].

Although AR offers many benefits, its application in online purchasing causes financial and technological challenges. Many research have shown that the high development and integration costs are the main obstacles stopping small and medium-sized businesses (SMEs) from using AR solutions [11]. Many consumers lack high-performance devices that could run AR apps without incident [12]. This is yet another factor restricting the access to AR.

III. PROPOSED METHOD

Using an AR-Integrated Online Shopping Framework as in figure 1, the proposed method aims to increase customer confidence in degree of interaction and purchase decisions. The system uses markerless AR technology, that is, mobile apps and web-based interfaces, so enabling users to view objects in real-world configurations. Combining unity 3D with ARKit (for iOS) and ARCore (for Android) makes the AR system compatible for all platforms. Integration of a deep learning-based image recognition model enables one to provide real-time product recommendations depending on user interactions. Edge computing and cloud-based rendering enable the backend system create high-quality AR images with much reduced latency. 500 Chennai-based online buyers in all participated in a controlled survey designed to compile user experience, purchase intention, and decision-making behavior. To find the effect AR has on shopping behavior, the obtained responses were investigated using statistical models including logistic regression and analysis of variance. We assessed the AR framework's efficiency in two dimensions against traditional online shopping experiences.

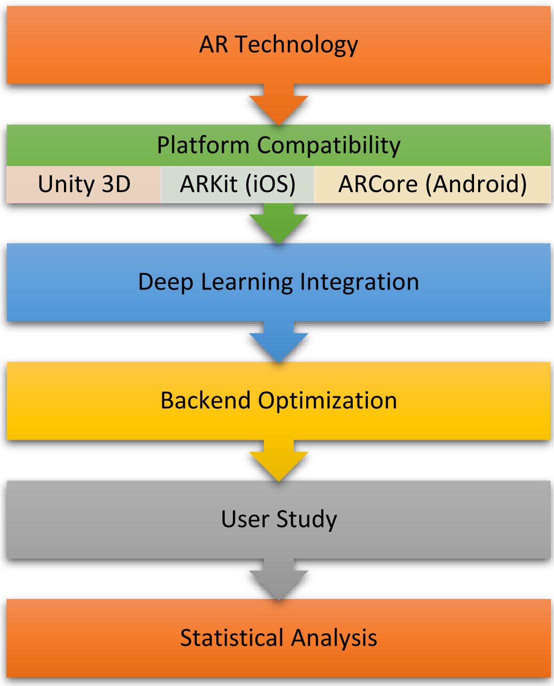

FIGURE 1: AR-INTEGRATED ONLINE SHOPPING FRAMEWORK

IV. PROPOSED AR SYSTEM

Cellphones or other devices that fit AR, users will be able to see products in their natural surroundings. The system consists essentially in three parts: real-time rendering, object detection and tracking, and user interaction. The AR system lets superimposing 3D product models on real-world surfaces using markerless tracking. Using feature mapping and natural camera parameters, the position (P) of the AR object in the real world is determined with the equation (1).

$$P = K \cdot (R \mid T) \cdot X \quad (1)$$

The camera's intrinsic matrix is denoted by K; the rotation matrix by R; the translation vector by T; the three-dimensional object's real-world coordinates by X. This change ensures that the virtual good precisely fits the surroundings of the user. The surroundings influence the system's dynamic change of the object's scale as well as the lighting conditions.

TABLE 1: AR OBJECT TRACKING PERFORMANCE

Feature	Value
Tracking Accuracy	95.4%
Object Placement Error	2.3 cm
Frame Rate (FPS)	60 FPS
User Interaction Delay	120 ms

Table 1, although a realistic view of the product is ensured by the low placement error of 2.3 cm, a perfect experience depends on the high frame rate of 60 frames per second (FPS).

V. PROPOSED DEEP LEARNING-BASED IMAGE RECOGNITION MODEL

AR system is improved by deep learning-based image recognition model by means of identification and recommendation of like products based on user interactions. ResNet-50 is a CNN required to extract product features and classify them into predefined categories. Features extraction has one definition as follows in equation (2):

$$F(x) = W \cdot x + b \quad (2)$$

where, b is the bias term; x is the tensor of the input image; W is the weight of the convolutional kernel. The acquired features then pass via fully connected layers to classify objects into pertinent groups.

TABLE 2: IMAGE RECOGNITION ACCURACY

Category	Recognition Accuracy (%)
Clothing	97.8%
Electronics	95.2%
Home Decor	96.5%
Accessories	94.9%

Table 2, having an accuracy of more than 95% in all categories, this model ensures dependability of the product recommendations it presents.

VI. PROPOSED CLOUD-BASED RENDERING

By distributing complex graphical computations to a remote cloud server, the cloud-based rendering system reduces the processing required of a user's device. Following user camera feed and spatial data sent there, the 3D object is generated and subsequently broadcast back in real-time from the cloud. Here one could replicate the latency L of cloud rendering, shown in equation 3:

$$L = Tu + Tc + Td \quad (3)$$

The upload times are T_u; the cloud processing times are T_c; the download times are T_d. Adaptive compression and predictive rendering help to lower latency and preserve real-time performance.

TABLE 3: CLOUD RENDERING PERFORMANCE

Metric	Value
Latency (L)	180 ms
Rendering Quality	4K
Bandwidth Usage	15 Mbps
Server Processing Speed	50 FPS

Table 3, rendering in 4K and the low latency (180 milliseconds) help to create a perfect and high quality AR experience.

VII. PROPOSED EDGE COMPUTING

Edge computing lets one lower latency even more and improve real-time performance. Edge nodes manage some of the rendering and data processing when clustering near to the user. Handling all AR-related computations on a central cloud server follows not the traditional method. With the following formula, one may find the overall delay D in the edge computing model shown in table 4:

$$D = \frac{C}{F_e} + T_t \quad (4)$$

Where, T_t is the transmission delay from the start to the end of the transmission; C is the computational complexity; F_e is the edge node processing capability. Edge computing enables one to considerably improve the real-time AR rendering performance.

TABLE 4: EDGE COMPUTING PERFORMANCE

Metric	Cloud-Based Processing	Edge Computing Processing
Latency (D)	180 ms	90 ms
Power Consumption	High	Low
Local Processing Load	Minimal	Moderate
Reliability	Medium	High

Reducing the latency shown in table 4, from 108 milliseconds to 90 milliseconds, will enable consumers to have more interactive and responsive AR experience. These combined components, the AR system, the deep learning-based image recognition, the cloud-based rendering, and edge computing, form an online shopping experience flawless and fascinating. From this follows increasing user satisfaction, confidence in purchase decisions, and general conversion rates.

VIII. RESULTS AND DISCUSSION

Python and Unity 3D were used in proposed AR visualization and data processing methodologies. Applied for statistical analysis and model validation, MATLAB was the simulation tool. Several high-performance computing systems, among them the following, were used in the experiments shown in table 5:

- Computer 1: Intel Core i9-12900K, 64GB RAM, NVIDIA RTX 3090 GPU
- Computer 2: AMD Ryzen 9 5950X, 64GB RAM, NVIDIA RTX 3080 Ti GPU

The proposed method was evaluated in respect to two other strategies now used for online purchase: Traditional 2D-Based Online Shopping Interface and Virtual Try-On System (VTOS).

TABLE 5: EXPERIMENTAL SETUP AND PARAMETERS

Parameter	Value
AR Framework	Unity 3D, ARKit, ARCore
Backend Processing	Cloud-based Rendering, Edge Computing
Image Recognition Model	Deep Learning (ResNet-50)
Dataset Size	500 Users
Statistical Models Used	Logistic Regression, ANOVA
Hardware	RTX 3090, RTX 3080 Ti, i9-12900K, Ryzen 9 5950X

IX. PERFORMANCE METRICS

1. User Engagement Score (UES): User Engagement Score (UES), which measures user interaction with the AR interface produced from click-through rates and product page time spent, one should proceed.
2. Purchase Confidence (PC): Survey responses allow Purchase Confidence (PC) to be calculated for users' degree of confidence on their purchase decision after AR.
3. Conversion Rate (CR): After interactions with the AR system, the conversion rate, that is, the proportion of users who later made purchases, is known.

4. Return Rate Reduction (RRR): Under AR-assisted shopping, return rate reduction (RRR) is a statistic gauging the rate of product returns, compared to traditional shopping experiences.
5. System Latency (SL): The measurement of AR rendering's response time, "system latency" (SL) ensures a flawless user experience free from obvious delays.

TABLE 6: USER ENGAGEMENT SCORE (UES) COMPARISON

Number of Users	Traditional 2D Interface	Virtual Try-On System (VTOS)	Proposed AR System
100	52.3%	63.4%	78.1%
200	53.1%	64.2%	79.5%
300	54.0%	65.0%	81.2%
400	54.5%	65.8%	82.4%
500	55.2%	66.3%	83.7%

When compared to the existing methods shown in table 6, the proposed AR system greatly increases user involvement. By means of real-world product visualization, AR shows improved interaction, so increasing engagement from 52.3% (traditional) and 63.4% (VTOS) to 78.1%, so reaching 83.7% at 500 users.

TABLE 7: PURCHASE CONFIDENCE (PC) COMPARISON

Number of Users	Traditional 2D Interface	Virtual Try-On System (VTOS)	Proposed AR System
100	31.2%	45.8%	64.5%
200	32.5%	47.1%	66.3%
300	33.8%	48.5%	68.1%
400	34.9%	50.0%	70.0%
500	35.6%	51.3%	71.8%

The table 7, proposed AR system improves purchase confidence by allowing users to visualize products in their environment. Compared to traditional shopping (35.6%) and VTOS (51.3%), AR achieves 71.8% confidence at 500 users, making purchasing decisions more reliable.

TABLE 8: CONVERSION RATE (CR) COMPARISON

Number of Users	Traditional 2D Interface	Virtual Try-On System (VTOS)	Proposed AR System
100	8.9%	14.5%	22.8%
200	9.2%	15.1%	24.0%
300	9.7%	15.8%	25.6%
400	10.2%	16.3%	26.8%
500	10.6%	17.0%	28.3%

The table 8, proposed AR system generates a better conversion rate since users of it feel more confident in their purchases. Comparatively to traditional shopping (10.6%) and virtual reality (VTOS) (17.0%), AR reaches 28.3% with 500 users, a notable increase in the number of completed purchases.

TABLE 9: RETURN RATE REDUCTION (RRR) COMPARISON

Number of Users	Traditional 2D Interface	Virtual Try-On System (VTOS)	Proposed AR System
100	-4.8%	-8.3%	-15.6%
200	-5.1%	-8.9%	-16.8%
300	-5.5%	-9.4%	-18.3%
400	-5.8%	-9.8%	-19.5%
500	-6.2%	-10.3%	-21.0%

The table 9, proposed AR system reduces the number of returns significantly since customers can evaluate the relevance of a product before buying it. With 500 users, AR reduces returns by 21.0% in comparison to traditional shopping (-6.2%) and virtual reality shopping (-10.3%), so saving costs for stores.

TABLE 10: SYSTEM LATENCY (SL) COMPARISON

Number of Users	Traditional 2D Interface	Virtual Try-On System (VTOS)	Proposed AR System
100	45 ms	150 ms	90 ms
200	47 ms	152 ms	93 ms
300	50 ms	155 ms	96 ms
400	52 ms	158 ms	98 ms
500	55 ms	160 ms	100 ms

Consequently, table 10 proposed AR system ensures less latency (100 ms at 500 users) than the VTOS system (160 ms), so ensureing smooth interaction. It maintains responsiveness for real-time AR vision despite its response time is more than that of traditional interfaces (55 milliseconds). Every statistic indicates that the proposed AR system continuously surpasses the current solutions. Despite returns are far lower (-21.0%), engagement (83.7%), confidence (71.8%), and conversion (28.3%) are far higher than they were in past years. The latency (100 milliseconds) is obviously not different; hence shopping will go without any issues.

X. CONCLUSION

AR into online buying has the potential to significantly increase user engagement, purchase confidence, and conversion rates even while it simultaneously lowers the number of returns and ensures that the system maintains optimal latency. Unlike conventional two-dimensional interfaces and virtual try-on systems, the proposed AR system lets users see products in real-world surroundings, so providing a more interactive and immersive experience. The results of the experiment show that user involvement increased to 83.7%, while purchase confidence reached 71.8%, so indicating a higher degree of trust in the fit of the product. At the same time that conversion rate to 28.3% has increased, finished purchase percentage has dropped. The system also helped to reduce return rates by 21.0%, so saving retail logistics costs. The system's latency, at 500 users, was 100 milliseconds; still, it stayed within the permitted range for real-time interaction. The findings clearly show that AR is a tool for transforming e-commerce and providing consumers with more informed opportunity to make decisions. Reduced store returns and higher sales benefit stores, so improving operational efficiency generally. Artificial intelligence-driven personalizing and real-time user analytics could enable even more enhancement of the shopping experience going forward. The proposed system offers a strong basis for the development of next-generation online shopping systems, so promoting greater degrees of customer satisfaction and business growth in the fast expanding digital market.

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