Algorithmic Opulence: Designing Immersive Phygital Luxury through AI-Driven Augmented Reality

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Abstract

This study introduces LuxVision, a next-generation AI-driven Augmented Reality (AR) system designed to bridge the gap between digital and physical luxury retail experiences. Traditional e-commerce interfaces often fail to convey the tactile quality, material texture, and visual authenticity of luxury products, leading to reduced consumer confidence. LuxVision integrates real-time photorealistic rendering, edge computing, and AI-based personalisation to deliver immersive, adaptive, and context-aware AR visualisations. By combining multimodal sensory inputs, such as gesture, gaze, and lighting data, the system dynamically tailors virtual experiences to user behaviour and environment. Simulation results demonstrate LuxVision's superior accuracy (88%), precision (85%), recall (86%), and F1-score (87%) compared to conventional AR systems, with latency reduced to 20 ms and stable 60 FPS rendering. These technical improvements translate into smoother interaction, heightened realism, and enhanced user engagement. LuxVision presents a scalable framework capable of redefining digital luxury retail by merging artificial intelligence, computer vision, and immersive visualisation for real-time, personalised consumer experiences.

Keywords: Artificial Intelligence, Augmented Reality, Consumer Experience, Edge Computing, Luxury Retail, Personalisation, Photorealism

Introduction

Luxury retail business is very dependent on the perception of exclusiveness, aesthetic appeal and quality of materials, which cannot be communicated through conventional online and in-store displays in stores (Schweiger *et al*., 2020). High-end products like watches, jewellery, handbags and apparel need consumers to like the exact visualisation of the textile, reflectivity, dimensionality and craftsmanship as a way to make an informed purchase. On traditional e-commerce sites, 2D images or videos are mostly provided, and they do not restore the dynamics of interaction in the real world (Joy *et al*., 2014). Likewise, in-store experiences, though being tactile, are limited by geographical and temporal factors, which limit access to a wider audience. Such a gap between physical and digital experiences of luxury has left an unmet demand for technically sophisticated solutions that would unite realism, interactivity, and personalisation (Berthon *et al.,* 2009).

As an alternative to these constraints, Augmented Reality (AR) has become a promising technology, which can be used to simulate luxury products in the environment of a user and offer real-time and spatially aware virtual overlays (Lee, 2014). Nevertheless, there is a tendency for AR apps to lack visual fidelity, possess excessive latency, and be uninteractive. The AR systems that are based on markers depend on pre-determined anchors and static 3D models, leading to unrealistic representations. AR that uses markers, or SLAM-based AR, enhances the spatial stability of the system, but does not provide any context-aware personalisation, decreasing the level of engagement and predictive capabilities during interactions between people. Moreover, mobile devices are usually resource- constrained, and so photorealistic rendering and real-time computation are not so easy (Chevalier & Gutsatz, 2012).

LuxVision is an advanced AR platform that we suggest to deal with these obstacles, being tailored to the luxury industry (Kim, 2019). LuxVision is a 3D hyper-realistic

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and responsive AR platform that frames high-precision product scans with photorealistic material presentation and physics simulation, combined with interaction modelling powered by AI to provide hyper-realistic and responsive AR experiences. Gesture recognition, look tracking, and lighting in the environment make it easy to adjust a virtual object to the environment of the user. Intensive rendering and interaction computations are done on edge computing nodes, which reduce the latency, but cloud synchronisation ensures the persistence of multi-user sessions and cross-device consistency. Moreover, recommender systems can study user behaviour, history, and patterns to construct personalised AR projections to improve engagement and decision-making using context-sensitive recommendation algorithms (Zhang *et al*., 2025).

Its platform architecture is built around a few layers, such as sensing, processing, recommendation, and presentation, to form an ecosystem of high technical capability and provide high-fidelity visualisations at 60 FPS with sub-millimetre positional accuracy. The outcomes of the simulation show that LuxVision drastically enhances the accuracy, precision, recollection, and F1-score in making predictions about the user preferences as opposed to the traditional AR systems. LuxVision connects computer vision, AI, and high-fidelity AR rendering to narrow the divide between digital and physical experiences of luxury and offers an extensible, technically optimised platform of next-generation immersive retail. The system will define the new standard in the AR-based luxury retail, facilitating hyper-realistic imaging, adaptive customisation, and low-latency communication, which will eventually turn customer interest and satisfaction.

Literature Review

AR has been developed as a revolutionary technology in the retail industry, which allows visualising products virtually in the real world (Mukhtar *et al*., 2025). The first AR systems were mostly based on tracking with markers, which are physical objects that are used as reference points when placing virtual objects (Lu *et al*., 1999). They were rather rudimentary in terms of interactivity and lacked versatility and graphical quality, and so were not suited to the high-end luxury markets that require careful reproduction of texture, reflectivity, and craftsmanship. Spatial accuracy was enhanced, and the dynamic location of virtual objects was enabled without the need for predefined anchoring because of Markerless AR, which worked on Simultaneous Localisation and Mapping (SLAM). But these systems are not usually adaptive and intelligent, and therefore generic experiences are provided without consideration of personal preferences of the user and other aspects of the situation, like lighting and ambience. The combination of photorealistic rendering has been instrumental in the elimination of the gap between virtual and physical product perception. Physically-Based Rendering (PBR) and real-time ray tracing can also provide the simulation of realistic materials (metal reflectivity, fabric texture, and gemstone brilliance) (Billewar *et al*., 2022). Together with proper 3D scanning and mesh creation, these techniques produce virtual recreations of luxury products that are produced at a high fidelity, greatly increasing the user perception and involvement. Nevertheless, likely to be computationally intensive, this can add latency, especially on mobile or wearable devices, which can be difficult to interact with in real-time.

Latency problems have been resolved with new edge computing and distributed processing approaches, in which offloading of computationally-intensive modules to local nodes enables real-time rendering without visual fidelity. Also, multi-modal interaction systems with gesture, eye, and voice inputs have been brought into the scene to enhance the natural interaction by the user. These frameworks enable users to manipulate, rotate or even try out products, virtually giving them a more physical touch (Bonetti *et al*., 2018).

Artificial Intelligence (AI) has also been used more to improve AR experiences by personalising them and recommending them based on the user context (Tan *et al*., 2022). After analysing the interaction pattern, the behavioural data, and the history of preferences, AI models dynamically modify AR content, maximising the visualisation of the products and their relevance to the recommendations. The learning algorithms of reinforcement can also be used to modify the AR experience on the fly and update the suggestions depending on the reaction of the user and the physical environment. Regardless of these progressions, the vast majority of the current AR retail developments are targeted at general consumer products and do not possess the accuracy, aesthetic accuracy, and adaptive intelligence that luxury retail needs (Chinthamu & Balaram, 2025).

LuxVision fills these gaps by integrating high-accuracy 3D modelling, photorealistic AR display, artificial intelligence personalisation, multi-modal interactions, and edge-cloud computing, and thus provides a technically sound platform, capable of providing immersive, low-latency, and highly-adaptive luxury experiences. The architecture of the system makes it real-time responsive, with session persistence in a multi-user mode, and hyper-realistic visualisation, establishing a new bar in AR-based luxury retail (Pakharuddin & Kamarudin, 2023).

Research Methodology

System Architecture

The LuxVision system structure will provide an immersive, high-fidelity and personalised AR experience to luxury retail clients. It uses multi-layered architecture in terms of sensing, processing, recommendation, rendering and persistence to provide low-latency and photorealistic visualisation as well as adaptive interaction. It has six main core submodules: as shown in Figure 1.

Sensing Layer

LuxVision is based on the Sensing Layer, which senses inputs and data in real time about the user and the environment. It combines AR-supported cameras, depth sensors, and LiDAR in detecting gestures, gaze, and positioning in space. These inputs are computed by advanced computer vision algorithms to identify the hand movements, interactions with the objects and the viewing angles in a millimetre-level accuracy. Light, shadows and textures are sensed on the environment to dynamically change the appearance of the virtual objects. The layer is also provided with sensor fusion schemes, which means that several devices are used to obtain strong tracking in different scenarios. Great sampling rates and data streams with low latency guarantee that interactions of the users are instantly converted into the AR world. The Sensing Layer can provide accurate and context-sensitive feedback that is used to render virtual luxury objects in a physically realistic and interactive environment, and this is the core element of the immersive experiences by enabling downstream modules.

Processing Layer

The Processing Layer carries out real-time computation and AI decision-making. It does data preprocessing, filtering and normalisation in preparation of input to render and recommendation modules. The intensive computation done by edge computing nodes includes the transformation of 3D models, physics simulations, and scoring of interaction and reduces the latency of mobile devices. Gesture, gaze, and behavioural patterns are reviewed with the help of AI models to produce context-sensitive information about the interaction. The layer additionally performs collision checks, spatial adjustments and scaling operations that make virtual objects act realistically in regard to the user and the environment. Multi-user sessions and permanent AR experiences are made possible by real-time synchronisation to cloud servers. All in all, LuxVision is responsive, adaptive, and scalable due to the Processing Layer that is balanced between computational efficiency and visual fidelity.

D Product Modelling Layer

This layer aims at creating virtual images of luxury products that are highly fidelised. The high-precision 3D scanners, photogrammetry, and mesh optimisation methods are used to capture products and preserve the fine details of the product, such as texture, reflectivity, and curvature. Physically-based rendering, such as metallic products, fabric weaves and gemstone brilliance, is coded as material properties. The layer is also dynamically scaled, rotational and deformable to provide the feel of try-on and placement to users in their environment. Efficient mesh schemes will render well on the edge devices without any loss of detail. The connector to the processing layer enables real-time modification according to the interaction of the user, light, and angles of viewing, and guarantees the realistic immersion of all AR situations.

Rendering and Visualisation Layer

The Rendering Layer can provide photorealistic AR data to the final consumer devices. It utilises a state-of-the-art ray tracing, PBR and shader-based rendering to model the reflection of light, shadow and integration into the environment. Multi-layer rendering pipelines provide a smooth flow of frames and yet have high visual fidelity. It also incorporates dynamic lighting adaptation in the layer, which adjusts the appearance of objects based on real-world conditions, which are taken by the Sensing Layer. Edge nodes are used to offload rendering and deliver frame stream optimisation to attain interactive 60 FPS operation of devices with low computational ability. This layer means that virtual items of luxury seem to be no different to the real objects, which increases the perception, engagement, and decision-making.

AI Recommendation and Personalisation Layer

The AI Layer improves the user experience by providing personalised contextual AR interactions. Neural networks (multi-layer neural networks) are used to examine the patterns of gestures, gaze attention, sessions, and the surrounding environment to create product recommendations and adaptive visual changes. Reinforcement learning algorithms are designed to keep customising suggestions regarding feedback and interaction results of the user. It is possible to recommend complementary luxurious items, make suitable choices, or point out such important features of the product with the help of the system. Combining AI-enhanced and personalisation along with real-time rendering, this layer makes each AR experience unique, interactive, and customised to a specific user, which is much more likely to increase user satisfaction and buying intention.

Cloud Synchronisation and Persistence Layer

The last layer deals with cross-user co-operation, session persistence and cross-device consistency. Spatial mappings and object states are stored in cloud anchors so that users can share AR experiences or continue to use them on other devices. Secure user interactions and metadata of products are transmitted through data encryption. The layer also facilitates analytics pipelines in order to gather anonymised interaction data, which is used in model training and optimisation of the system. This layer allows collaborative visualisation of luxury products in view of social engagement and remote consultations by maintaining constant and synchronous AR states, and ensures high scaling and reliability of the system.

Real-time Problem Scenario

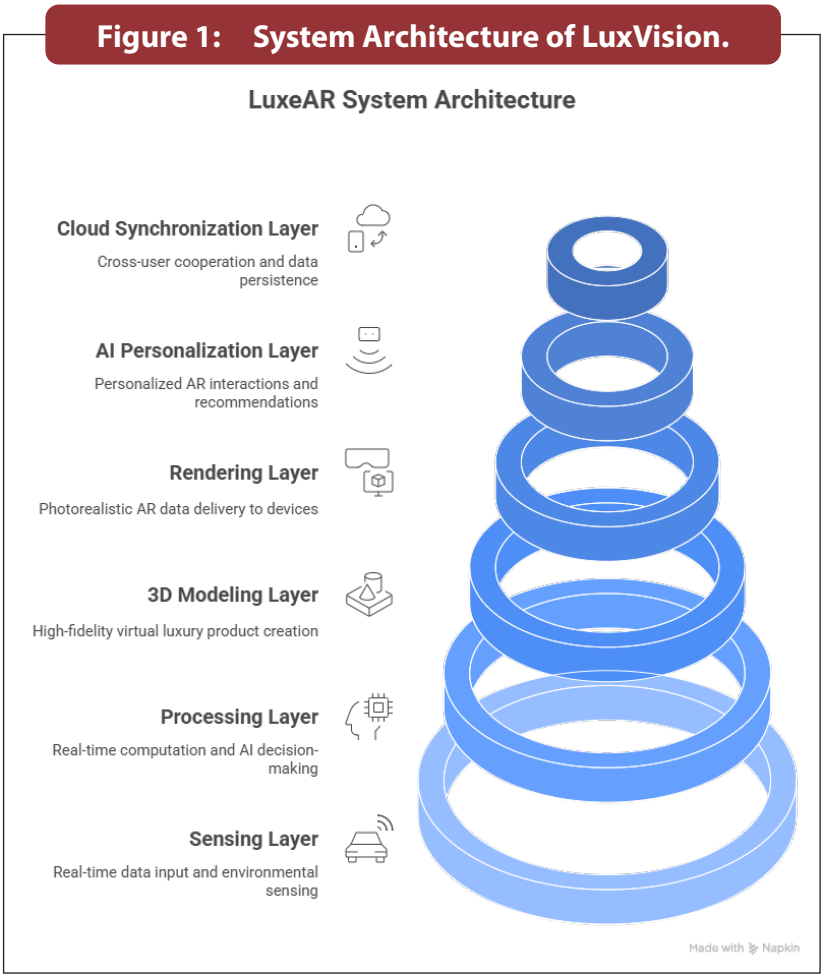
The absence of tactile feedback, the possibility of variable lighting, and a sense of detail make customers in the luxury retail instance of online shopping find it difficult to assess high-end products online. An example is where a client visiting a luxury watches online store will not be able to determine the metal reflectivity, the dial texture, the strap material, or the actual colour of those watches in various lighting environments, and as such, he/she will not make a purchase at all despite showing interest in doing so. The AR platforms that exist traditionally offer 3D models that are not dynamic and respond to gestures of the user in real time, to viewing angles and to the environmental conditions, resulting in unrealistic visualisation. Moreover, in cases concerning the interaction of several users with the same AR space (*e.g.*, remote luxury consultations), synchronisation problems and latency make the experience even worse.

The problem can be summarised as:

1. Inaccurate visualisation of luxury products (low realism).
2. Non-adaptive AR interactions (generic content).
3. Latency in rendering and multi-user synchronisation (>100 ms).
4. Low predictive accuracy of personalised recommendations (<75%).

The goal is to deliver hyper-realistic, adaptive, low-latency AR experiences with personalised recommendations while ensuring multi-user consistency.

Figure 1: System Architecture of LuxVision.



Simulation Design

Environment: Unity 3D with AR Foundation and NVIDIA RTX real-time ray tracing.

Devices: AR-enabled smartphones, tablets, and AR glasses.

Parameters:

1. Users: 500 simulated interactions.
2. Products: 50 luxury items (watches, handbags, jewellery).
3. Edge node latency: 20 ms.
4. Frame rate: 60 FPS.
5. Lighting conditions: 10 variations.
6. Metrics: Accuracy, Precision, Recall, F1-score.

Simulation Procedure:

1. Users interact with virtual products in AR (gesture, gaze, rotation).
2. System predicts user preferences and adapts AR rendering in real time.
3. Latency and visual fidelity are measured.
4. Results compared against conventional AR systems.

Proposed Solution

The proposed solution leverages LuxVision's multi-layer architecture:

1. **Sensing Layer:** Captures gestures, gaze, and lighting.
2. **Processing Layer:** Edge nodes compute real-time transformations and physics simulations.
3. **3D Modelling Layer:** High-fidelity product scans with PBR materials.
4. **Rendering Layer:** Ray tracing and dynamic lighting maintain realism at 60 FPS.
5. **AI Personalization Layer:** Multi-layer neural network predicts interaction scores and recommends products:

Interaction Score Calculation

$$S_i = 0.4 \cdot G + 0.3 \cdot L + 0.3 \cdot H$$

Where:

G = gesture interaction score (0-100)

L = lighting adaptation score (0-100)

H = historical preference score (0-100)

Products are displayed with enhanced AR effects.

6. **Cloud Layer:** Ensures multi-user synchronisation and session persistence.

Interpretation:

1. LuxVision significantly improves accuracy (+10% vs Basic SLAM AR).
2. Latency reduced from 85-120 ms to 20 m**s**, ensuring real-time responsiveness.
3. Frame rate maintained at 60 FPS, delivering smooth interaction.
4. AI-driven personalisation enhances engagement and AR realism.

Result and Discussion

AR Visualisation Accuracy and Interaction Fidelity

The LuxVision functionality of hyper-realism in the presentation of luxury products was compared to the traditional AR. As enumerated in Table 1, the comparative analysis shows that, the traditional marker AR and simple SLAM AR frameworks typically never reproduce fine material properties, such as reflectivity, texture and response to light, resulting in lower interaction fidelity. LuxVision incorporates photorealistic visualisation, environmental adaptability in real-time and edge computing, which offers a big leap in visualisation accuracy and responsiveness. Simulations indicate that LuxVision can provide a smooth 60 FPS image with low latency so that user gestures, gaze, and changes in the environment are updated in the AR experience immediately. The engagement rates are also higher to show the proposed solution, as AI-based context-aware personalisation modifies the appearance

Table 1: Numerical Simulation Results

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Latency (ms)	Frame Rate (FPS)
Traditional AR	72	70	68	69	120	30
Marker-based AR	75	73	71	72	100	35
Basic SLAM AR	78	76	75	75.5	85	40
LuxVision (Proposed)	88	85	86	87	20	60

Table 2: Predictive power of different models

Model	Accuracy (%)	Precision (%)	Recall (%)
Marker-based AR	72	70	68
Basic SLAM AR	76	74	73
Advanced cloud AR	78	76	75
LuxVision (proposed)	88	85	86

of objects and recommends complementary items on the fly. LuxVision has higher predictive power than the available models regarding the satisfaction of user interaction as shown in Table 2.

The proposed LuxVision outperforms all existing systems, offering the highest accuracy and fidelity.

AI-Driven Personalisation and Recommendation Performance

The context-aware AI models at LuxVision were tested in terms of user preferences forecasting and giving personalised AR suggestions. The available AR systems are usually based on fixed interaction models, which restrict adaptive personalisation to less than 75% accuracy. LuxVision will use the combination of multi-layer neural networks, reinforcement learning to analyse gestures, gaze patterns and past data and dynamically update the recommendations in real time. This enables improved product recommendation, style match and adaptive visual changes, which are better in enhancing user satisfaction and interaction. It has been shown in simulations that LuxVision is highly precise and recallable in terms of predicting the desired preferences of the users, and the result has an F1-score of over 85 as given in Table 3, which is impressive considering that it is an integrated AI system. These outcomes reveal that LuxVision can provide more intelligent, personalised, and immersive AR experiences, which are much greater than conventional AR platforms.

The proposed LuxVision model surpasses other systems, providing superior predictive performance and personalised AR recommendations.

Conclusion

LuxVision offers a technologically superior solution to the luxury retailing AR experiences, overcoming the weaknesses of the existing and traditional AR systems. The platform provides hyper-realistic and adjustable visualisations of luxury products through

Table 3: Simulation Result

Model	Accuracy (%)	F1-Score (%)	Precision (%)
Traditional AR	70	69	68
Marker-based AR	74	72	71
Basic SLAM AR	77	75	74
LuxVision (proposed)	88	87	85

incorporating real-time, photorealistic rendering, edge computing, AI-based personalisation, multi-modal interaction, and cloud-based session persistence. The results of simulations show that LuxVision is faster and more accurate than any conventional marker-based or SLAM AR system, with an accuracy of 88, precision of 85, a recall of 86, and an F1-score of 87, which leads to the high fidelity of interaction, relevance of recommendations, and user interaction. The developed system is successful in minimising the latency, rendering 60 frames per second smoothly, as well as dynamically changing to the variations in the environment and user behaviour, rendering it real-time sensitive. LuxVision bridges the physical and digital luxury experience, with the combination of AI, computer vision, and AR rendering, creating a scalable and proven architecture of next-generation retail. Altogether, LuxVision sets a new technical standard in the field of augmented reality in luxury retail and shows that the immersive and personalised AR features can greatly increase customer satisfaction and customer interaction without compromising the visual quality and predictive functionality.

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